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WAVE-FORMED CUSPATE FORELANDS.*

By R. S. TARR, Ithaca, N. Y.

Nature of the Study.

In an important paper discussing the origin of cuspate forelands, Mr. F. S. Gulliver† divides these land forms into three main classes, according to origin,—current (meaning the oceanic circulation), tidal and delta. Wind waves and wind-formed shore currents are not considered among the effective causes. While it is distinctly my opinion that the wind is nearly everywhere the chief and most common cause for the formation of such shore features, I can do no more here than to state this opinion. Nevertheless, whether this personal conclusion is too broad or not, wave action must be admitted as a fourth cause, and I believe that investigation in the field will show that it is the most efficient of the four. The chief object of this article is to show that at least some cuspate forelands are wave-built.

I have studied the formation of projecting forelands in two places, one on the shores of lake Cayuga, the other in the partly enclosed waters of Cape Breton island, north of the Nova Scotia peninsula. In the latter place hooks, bars and

*The work at Cape Breton was done in the early summer of 1896, and the publication was delayed in the hope that I should be able to make a more detailed study in 1897; but this proved impossible, and as I may never visit the region again I have thought it well to call attention to these deposits.

†Bull. Geol. Soc. Am., vol. VII, 1895-6, pp. 399-422.

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cuspate forelands are developed in a wonderful degree of perfection. In lake Cayuga there are three prominent forms of projecting forelands, the delta, the modified delta, and the spit (sometimes partly hooked). The delta represents merely the dumping of debris brought by a stream into the lake, accompanied by a certain modification by lake waves and currents. Sometimes the supply so far exceeds the action of waves and currents to remove it, that the delta form remains perfect; but at times it is considerably modified by the action of lake waters.

Spit on Lake Cayuga Shore.—On the shore of lake Cayuga the modification of delta form has been mainly the result of wave work. This would be inferred from the size of the pebbles which occur on the delta front; and the truth of the inference is verified by a very slight study of the shore. In any body of water, but particularly in a narrow body with rather high valley walls, the direction of the wave attack is in nearly all cases diagonal to the coast. Only rarely can the waves advance directly upon the shore in a direction normal to it. In a narrow valley of some depth, the waves that do reach the shore at right angles to the trend of the coast are slight in effect, for they have only the breadth of the valley in which to form. It is the waves that advance most nearly parallel to the coast that are the largest, and hence the most effective.

Therefore in a narrow and deep lake valley, like that of lake Cayuga, the most effective, as well as the most violent waves, come either diagonally or parallel to the coast. (Pl. I, Fig. 1). These may pass from a northerly or from a southerly direction; but in this lake the winds from the north are on the average more violent and more permanent than those from the south. Hence the conditions are these: in the great majority of cases the waves extend more or less parallel to the coast, and those from the south are less powerful and permanent than those from the north. This produces a decided effect on the topography of the lake coast line. In the case of the deltas there is usually more modification on the north than on the south side. Sometimes this consists of the addition to the delta of wave-derived debris, wrested from the cliffs, and in other cases the driving of stream material

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to the south. Very slight local conditions will determine which of these results will be accomplished, and as these vary the delta form likewise changes.

The effects of these two sets of waves sometimes builds spits, which reach directly out into the water, possibly curving at the end; and when they do so, curving toward the south. Sometimes these spits are supplied with debris mainly by streams; but in others, and in one very notable case, Crowbar point (Pl. I, Fig. 1), a few miles north of Ithaca, the spit is supplied entirely by the waves. It is made of shale pebbles, and projects directly out into the lake from an exposed point where the direction of the shore turns somewhat.

This is distinctly an instance of the efficiency of wave work, both in supplying the materials and in building them into projecting forelands. Pebbles are brought from the south and from the north, and at this particular point the battle of the waves has driven them out into the lake. The predominance of the north winds has turned the end of the spit somewhat toward the south. Here then is a case, not indeed of a true cuspate foreland, but of a closely allied form, that is wave built. There is no stream supply, there is of course no notable tidal action in the lake, and the action of currents is not competent to move the coarse material. Shore currents of wind-drift origin, often lasting long after the exciting cause has disappeared, are well known in lake Cayuga, and they are doing work; but even during the most violent winds, one will never find currents of sufficient power to transport pebbles weighing from an eighth to a quarter of a pound.

There is but one cause left, and this is the waves themselves. These are abundantly able to perform the work, and to me would occur first of all as a most probable cause. One has but to watch the waves work to see how natural is this action. Passing nearly parallel to the coast, or, as for that matter, diagonally to it, the wave breaks and moves forward as a surf of considerable force. By this forward movement the pebbles are picked up and pushed along the shore. Again and again this is done, as wave succeeds wave, and gradually the pebbles migrate toward a place where they must come to rest, either in the deep water, or else in the lee of a point. To this place both the north- and south-moving waves may be

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bringing materials, and hence a point grows outward. The shore currents are operating in the same direction and hence are coöperating; but they are doing much less than the waves, and are moving only clay and sand, which of course, are made to enter into the structure of the spit.

One may well ask why the spit began, and when it will end. I am not certain that I fully and clearly understand this point, though I see plainly that it is through no chance or accidental conditions that the spit develops. It has an explanation in the law, everywhere illustrated on coast lines, that waves supplied with material will discover the easiest means of disposing of it. In the case of Crowbar point the waves were, in the first place, driving materials both ways, the south winds pushing the pebbles toward the north and the north winds driving them in the reverse direction. There was a bend in the coast due to the projection of the old land; to this the waves from the south brought materials, but there they lost some of their power, and hence could not continue to carry all their load beyond the point, so some was dropped on the very point. The same was true of the waves from the north. They were able not merely to drive along the materials which they had wrested from the rocks, but also to turn back some of the debris which the south waves had driven beyond the point. But when these waves passed the point *they* lost their force likewise, and so both north- and south-moving waves made this a dumping ground. As they built the spit out into the water, the interference of the point with the movement of materials to the north or south became greater and greater, until, at present, the spit forms an almost perfect barrier for the larger fragments. Had the south waves been greatly less powerful than those from the north, there would have been built a bar extending nearly parallel to the coast; but with nearly perfectly balanced waves from the two directions, the spit must grow directly outward.

The other question is whether the spit will continue to grow outward indefinitely. Granting the continuation of the present conditions, the spit must finally destroy the cause for its further extension, and, I believe, as the next stage, become a hook, bending toward the south.

As it grows out into the lake, enough material is still driven

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up to its base, and part way out on the spit, to influence the wave, which then reaches it in a direction normal to its length. So by growing outward, the direction of the shore is actually changed, and hence the mode of wave action. Passing diagonally to the old land, the wave now strikes the foreland at right angles. Of course an equilibrium will be maintained; the change in direction of the shore will not be so great that the wave-brought materials cannot be disposed of, though if it were the pebbles would be deposited at the base of the spit, and thus lessen the angle between the oldland and the new. However, as the spit grows outward, the *necessity* of transportation of wave-derived fragments decreases. On the new land the waves beat directly, and as they wash directly on and off the beach they grind the pebbles to and fro, keeping them in nearly the same place. Both sides of the spit then become mills in which the pebbles are ground. Before long they are so worn down that the undertow and shore currents can carry the ground-up fragments, though their place is speedily taken by others.

Hence, as the spit grows outward, the pebbles that are supplied have to run the gauntlet of wave attack from waves washing directly on the shore; and the *longer* the spit grows, the less chance is there of pebbles being carried very far toward the end. In the first stages of the spit development *many* pebbles would be carried to the end, and deposited, rapidly lengthening the new land. Then the number would *rapidly* decrease as the length of the spit increased, and finally the number that reached the end would *slowly* decrease, when the spit would lengthen with extreme slowness. In this stage, of all the fragments driven to the base of the spit, only a small portion would escape comminution and widespread scattering. This part, carried on to the end would finally be so slight in amount that the spit would actually cease to increase in length; for the supply at the end would not exceed the ability of the waves and the currents to carry it away, and dispose of it in some other place.

In this stage the spit might be changed to a hook, bending toward the south; for the waves and currents from the *north* would be able to drive the materials around the end, after the ability of the south waves to do so had ceased. In

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any *particular* case the point at which the spit should become a hook would depend upon the relative strength of the spit-forming forces; but the hook *would be a permanent form* just so long as the conditions remained uniform. That is, once begun, during a certain stage of development of a spit, and in a certain part of a lake, a hook would *always* remain in this position unless the spit-forming conditions varied. This would involve a change in either the relative *strength* of the waves, the *direction* of wave supply, the amount of *material* furnished, or the *position* of the base of supply. Variations in these directions can come only by a change in the neighboring land, either in relative level of land and water, or as the result of erosion. Either of these causes may change the natural base of the spit, or cause the waves to commence work on a different kind of rock, or change either the direction or relative force of the waves.

Spits should therefore vary greatly in length, width, position and details of form, according to the various sets of controling forces and conditions. They may vary in width, even up to the form of cuspate forelands. There seems to be every gradation between spits and these compound bodies, as there certainly is sometimes a close relation in cause. From place to place hooks should also vary greatly in direction, in form, in length, and in the nature of the spit pedestal. In reality they do. Probably a close study of these would show a definite relation between form and surrounding conditions.

Cuspate Foreland in Sydney Harbor, C. B.—In the harbor of Sydney, Cape Breton island, there is one of the best instances of a cuspate foreland that I have ever seen (Pl. I, Fig. 2). It is probably less than a mile and a half across its base and considerably more than a mile long, and its northern and longer side faces the more open water. On the south side there is an opening near the base, through which the tide enters and passes into the lagoon inclosed between the sides of the foreland. The bottom of this lagoon is a mud flat, during low tide exposed to the air in the greater part of its area, but transformed to a bay at high water. Upon the point formed by the union of these two arms there is a light house, and beyond this, off the point, is shoal water for some distance, though on either side the harbor is deep and navigable by even large ships.

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There is no stream supply for this foreland, but the source of the material is the cliffs of Carboniferous sandstone and shale at the base of the bar (Pl. II, Fig. 1). On the northern or seaward side these rise as wave-cut cliffs, and from their base there extends outward, toward the end of the bar, a beach of large, wave-wrested fragments. These become smaller in size and more rounded as the end of the bar is approached; but even at the light house, which stands on the very end, the beach is in large measure made of pebbles. This part of the harbor is exposed to heavy waves from the north, and, aside from the cuspate foreland itself, there is other evidence of their action. The cliffs are distinctly wave-cut, the beaches contain large rock fragments, and the beach-face of the bar is high, showing evidence that the waves at times attain great force and power. On the southern side there is much less activity, and here the bar is less perfectly developed.

It is said that this cuspate foreland is wave built. There is direct evidence of this in the hight of the bar, the nature of the materials and their evident source. The same conclusion can be reached by the process of elimination. The foreland is not stream supplied, for there are no streams at its base. It is not the result of currents, for these could not move the larger materials; and, moreover, the people familiar with the harbor say that there are no rapid currents. The foreland is not the result of tidal action for the same reason; the rise and fall of the tide is slight and there are no very marked tidal currents. The ferries running from Sydney to North Sydney pass close to the point several times a day, and the captains of these boats assured me that there were no very noticeable currents, excepting the gentle inflow and outflow of the tide.

In this case, as in Crowbar point on lake Cayuga, the waves have driven materials along shore until a slight change in the direction of the coast has been reached, and then have driven this material out into the bay. The less powerful southern waves have done the same; but here a single spit has not resulted, mainly because of the greater force of the north waves, which have caused the end to be deflected to the south, but partly because the change in direction of the

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shore is rather gradual, so that the place of beginning of the two arms which form the cusp was different. No doubt the winds from the opposite side of the harbor have helped to build the bar on the inner or southern side by driving toward the shore some of the materials from the end of the bar which is being built outward by the waves from the northern and more open water. In this connection it is suggestive that the southern arm is mainly sand, while the northern is mainly pebbles.*

Here, as in the case of Crowbar point, the result of the wave action has been to absolutely change the direction of the coast, so that the larger waves in this place now reach it in a direction nearly normal, rather than parallel to their crest lines. They drive materials along shore to the base of the bar, and then up and down it, where they are ground fine enough to be in large part removed, either in the undertow, or in the currents, or along the bar to its end, where they are in part deposited to lengthen the foreland, and in part drifted around the point to help build the bar of the southern side.

Although it is difficult to understand these processes in the present state of our knowledge of shore lines, it seems evident that there is an attempt to establish an equilibrium between wave force, wave direction and sediment supply, and that these shore forms are an expression of this attempt, which here has reached a more or less complete degree of success in the establishment of the equilibrium. No doubt tides and currents modify this somewhat, but in this case they are distinctly subordinate. I am certain that a careful study of any particular foreland, taking into account its form, the nature of the material supplied, the depth of the water, the action of the tides and currents, and particularly of the waves, will in each case determine the history. We need such studies as these before we can really understand the details of the processes by which these interesting shore features are being made.

The Bars of the Bras d'Or.—In no place have I ever seen a more remarkable development of various kinds of bars,

*I believe that the chief cause for the southern arm is that mentioned later in the paper in a consideration of the cusps of the Bras d'Or lakes.

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hooks, spits and cuspate forelands than in the Bras d'Or lakes of Cape Breton island. These so-called lakes are really drowned valleys, occupied by the sea, and nearly land-locked, with a wonderfully intricate shore line and a complex maze of islands, peninsulas and interlocking bays. In some places the bays are several miles broad, in others mere fjords, a few hundred yards across, in which there is no opportunity for the development of currents. The tide rises but two or three feet, and the testimony of the people who live on the shore is that there is no noticeable development of currents. The sole important cause for the movement of materials along the shore is the wind, which produces small, though very noticeable waves, and of course also some slight shore currents.

There are wonderfully perfect bars across bays, islands joined to the mainland by bars (Pl. III, Fig. 1), cuspate forelands of perfect form (Pl. III, Fig. 2) and hooks (Pl. II, Fig. 2, and Pl. IV, Fig. 1) of various shapes. I had but a day in which to examine a few of these, and hence got very little where I believe it is possible to learn a great deal about shore lines. Waves were everywhere seen to be the cause of the shore features, not merely because other agents were absent, but also by the direct evidence of the material composing the bars. In most parts of the narrow Bras d'Or there is a migration of material along the shore. Here and there this has necessitated the formation of a bar across a bay, thus altering the coast somewhat; and now and then an island has been tied to the coast by bars on its landward side (Pl. III, Fig. 1). In still other cases the coast has been built outward, and made more irregular.

I am not certain that some initial cause is always necessary for the accumulation of a V-shaped bar of wave origin, though wherever I have seen them there is always a change in the oldland coast line (Pl. III, Fig. 2). It looks as if there was first of all an accumulation of material that had been driven along the shore to some place where further progress was retarded; and that, after a beginning had been made, the process was accelerated by the increased obstacle, as in the case of the lake spit. This process continues until a bar is constructed, upon which the materials supplied may be ground down and removed. When this is done, and the materials at

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the end are either in the form of small pebbles or sand, the bar may be sharply turned in the direction away from that of the prevailing wind.

This turning point is apparently reached and caused whenever the force of the waves which reach the end of the bar, from the direction in which the wave movement is most powerful, is able to remove the materials which the waves from other directions are driving to the end. That is to say, there comes a balance of supply and ability to remove, when the further out-building of the bar must cease. Then there is an abrupt bend.

This is very well illustrated in the Barrachois hook (Pl. II, Fig. 2, and Pl. IV, Fig. 1), on the eastern side of the Bras d'Or, about midway between North Sydney and Grand Narrows. It is plainly visible from the train and is a remarkable feature, being set in the dark waters of a deep and narrow arm of the sea extending between two high hills. It reaches directly out from the shore, turned at an angle of about 110° with the coast, which is the normal angle of the bars forming the arms of the cuspate forelands in this region. At a distance of about one hundred or one hundred and twenty-five yards from the shore it bends abruptly, at an angle of 60° or 70° (Pl. II, Fig. 2) and extends nearly parallel to the coast, until near its end, at a distance of two hundred or two hundred and fifty yards from the first elbow, it turns again toward the shore and then back in the opposite direction, forming a very perfect hook.

This hook is built out into water which is sixty feet deep, and hence it represents a *distinct bank*, which has been piled along this line as the result of remarkably permanent conditions. It is due to no mere chance, but to the operation of some very distinct forces, operating for definite causes, in perfectly definite ways for a considerable time. In this case the cause for the bend seems evident. It is a place where the along-shore waves from the south (left) can transport the diminished supply of materials which reach the end of the bar, and do this so speedily that the bar can reach no further outward, but must turn. This change comes with such force and persistence that it is posible to build the turned end for more than two hundred yards in a depth of sixty feet of

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water.* At the end of this there is a hook, no doubt because the weaker winds from the north (right), which have only a very narrow and protected valley in which to blow, are able to turn the supply backward toward the south, under the protection of the bar that has grown northward. In other words, the supply driven along this bent end is not sufficient to build the bar further north in opposition to the tendency of the very weak opposing waves to drive the materials backward.

In the Bras d'Or there seems to be evidence that under certain conditions a hook will change to a cuspate foreland. This has been partly stated above in the explanation of the Barrachois hook. There, in an enclosed arm of the sea, a bar that is growing outward is bent, not directly back *toward* the coast, but up the channel before the stronger waves. In the more open waters of the Bras d'Or, heavy waves often come directly upon the shore, or else reach it at a high angle. Such action will naturally tend to interfere with the *outward* growth of a bar which is being constructed by the drift of materials before the waves that reach the shore diagonally; and when, finally, the outward growth of this bar becomes slow, because of diminished supply, the on-shore wind waves at first produce a hook at the end, and then commence to build a bar toward the shore (Pl. IV, Fig. 2). There are several cases of this nature in which a bar, proceeding outward for some distance, turns landward and produces a partial hook, which is apparently an incomplete V-shaped cuspate foreland. In other cases a small bar is starting out from the land to meet the recurved end of that arm which has developed most notably (Pl. III, Fig. 3). Then we have a nearly complete cuspate foreland, which would be complete if the end of the recurved bar, and that of the small one extending out from the shore, were finally united. Such, I believe, is the origin of many, and perhaps all, of the cuspate forelands of the Bras d'Or; and there seems to be nearly every gradation between the single bar, the bar hooked at the end, and the double V-shaped cuspate foreland.† The nearly soldered

*The water is shallower on the inner side of the hook, but even here is deep.

†It happens that the two illustrations of these gradations here reproduced are from bars of a very similar nature, whose basal ends are on islands which the bars are engaged in tying to the mainland. Here cuspate forelands are built, though they are made to include off-shore islands.

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southern arm of the Sydney harbor cusp described above appears to be an instance of an almost closed foreland of this origin.

It would be unwise to extend the results of this study so far as to make the generalization that all cuspate forelands are derived by means similar to this; but before assuming that they are not so formed it seems that we should have distinct evidence that they are not. Is there any place where the peculiar eddying of tidal currents is known to be at work building these shore features? Have we any distinct evidence of the existence of back-set eddies from the Gulf stream, whose power is sufficient to move and guide the distribution of materials? Such eddies, to cause the prominent cusps of the Florida coast should, it seems, be very noticeable. It is possible that this evidence has been brought forward; but if so I have never seen it.

As small spits and cusps may be made by waves in small, enclosed and nearly land-locked bodies of water, where proper conditions exist, so it seems possible that larger cusps, even those as large as Hatteras, may be made where the supply of material is more rapid and of finer texture, while the waves are greater and the shore currents of wind origin more powerful and therefore able to move the fine materials. This certainly seems a *possible* explanation; and, even though it be not the correct one, it should at least be discussed as an hypothesis, and the evidence against it definitely brought forward, if there is such opposing evidence.

OSAGE VS. AUGUSTA.

By Stuart Weller, University of Chicago.

In a recent article in this magazine* entitled, "Use of the Term Augusta in Geology," C. R. Keyes defends the use of the term Augusta (Keyes) and its displacement of the older term Osage (Williams) as the name of one of the major subdivisions of the Mississippian series.

The science of paleontologic geology is a historical science. It is something far more than the mere classification of rock

*Am. Geol., vol. XXI., p. 229, April, 1898.

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strata. In his investigations of the Lower Carboniferous faunas of the Mississippi valley Prof. H. S. Williams detected the records of three distinct chapters in the history of the continental interior, and to the middle one of these chapters he gave the name of Osage, the rock strata containing the fossil records of the chapter being designated as the "Osage group." It was recognized that the faunas of the Burlington and Keokuk limestones were a unit in themselves to such an extent that they should not be divided into several distinct groups, as had generally been done by earlier geologists. There were life changes in progress during the time of deposition of these limestones, but they were internal, evolution changes, not dependent upon profound physical changes or upon the immigration of new forms of life. The records of the Osage chapter in our continental history were found to be best expressed in these faunas of the Burlington and Keokuk limestones.

Mr. Keyes' contention that the Osage and Augusta are not synonymous, because Williams failed to include a portion of the so-called Warsaw group of older authors in his division, is based upon unessentials and is not tenable. On the same ground, if some future investigator were to find that a small portion of the Chouteau limestone would be better placed with the superjacent strata, it would be perfectly legitimate for him to ignore both the names Osage and Augusta, and to propose still a third, and so still further increase the confusion.

As a matter of fact, Williams did recognize that one portion of the Warsaw faunas were of Osage age and another of St. Louis age; and he showed, before Mr. Keyes, that the fauna of the Warsaw group had no separate place in a natural classification of the Mississippian faunas. He says:* "The faunas of the Chester, St. Louis and most[not *all*] of those referred to the Warsaw formations are paleontologically more closely allied than they are to the faunas of the Keokuk and Burlington." It is thus seen that he carefully excludes a part of the Warsaw faunas, and clearly implies their relationship with the Osage faunas. That Mr. Keyes and Prof. Williams are in accord in this regard is shown by the following statement by Mr. Keyes:† "In a majority of cases the so-called

*U. S. Geol. Surv., Bull. 80, p. 169, 1891.

†Geol. Surv. Iowa, vol. I., p. 70, 1893.

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Warsaw is clearly the lower part of the St. Louis limestone."

Prof. Williams' classification of the strata of the Mississippian series is expressed in tabular form as follows:*

Mississippian Series.	Genevieve group.	Chester. St. Louis. Warsaw. (in part).
	Osage group.	Keokuk. Burlington.
	Chouteau group.	Chouteau limestone and Vermicular and Lithographic formations as proposed by G. C. Broadhead, in the following report.

In this way the name Osage was established in 1891. In a paper† bearing the date of June, 1892, Mr. Keyes accepted *without question* and with no intimation that the name was used "provisionally," the name Osage and used it in a classification of the strata of the Mississippian section, giving it the following definition:

OSAGE LIMESTONES.

Definition and general Relations.—From a purely paleontological standpoint, the advisability of including the Burlington and Keokuk limestones under a single name was pointed out several years ago. For this long needed term Williams has proposed the name "Osage."

At that time nothing was said about the name being proposed under the "misconception" that the Burlington and Keokuk faunas were mingled in southwestern Missouri,—a "misconception," which, if it ever did exist, would have no bearing on the subject. Neither did the supposed fact that Williams had entirely excluded the "Warsaw" from his Osage group seem to be a serious objection to Mr. Keyes, at this time, against using the name. The following tabulation of his classification of these strata is given by Mr. Keyes in this paper:

*U. S. Geol. Surv., Bull. 80, p. 169, 1891.

†Bull. Geol. Soc. Am., vol. 3, p. 283.

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Mississippian Series.	Kaskaskia group.	"Chester shales." "Kaskaskia Limestone." Aux Vases sandstone.
	St. Louis group.	"Ste. Genevieve limestone." St. Louis limestone. Warsaw limestone (in part, not typical).
	Osage group.	Warsaw shales and limestone (typical). "Geode bed." Keokuk limestone. Upper Burlington limestone. Lower Burlington limestone.
	Kinderhook group.	Chouteau limestone. Hannibal Shales. Louisiana limestone.

In 1893, at the time of publication of volume one of the Iowa geological survey, the "misconception" under which the name Osage was proposed had been discovered by Mr. Keyes, and the name Augusta was proposed as follows:*

AUGUSTA LIMESTONE.

This term is applied to those rocks exposed in the Mississippi valley which have hitherto been called the Burlington and Keokuk limestones.

In this initial definition of Augusta, no mention is made of the Warsaw, but in the general classification of the strata the Warsaw was divided between the St. Louis and the Augusta in the same manner in which it was divided between the St. Louis and Osage in the previous paper. That the name Augusta was recognized at this time as synonymous with Osage, is shown by the following sentence:† "In the meantime Williams suggested for this limestone the title 'Osage,' from the name of the chief river of southwestern Missouri, which cuts through some of the Lower Carboniferous series in Saint Clair county." Apparently the only reason in the mind of its author for the proposal of Augusta, was his belief that it was a better name than Osage.

*Iowa Geol. Surv., vol. I, p. 59.

†Loc. cit., p. 59.

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As to whether Osage or Augusta shall stand as a term in American geology can only be settled by impartial judges. Osage clearly has priority and has been adopted by Dana* and by Scott† in the two latest text books of the science. The name was also adopted by the late geological survey of Arkansas. The name Augusta has been used only by the geological surveys of Iowa and Missouri, with which Mr. Keyes has been personally associated.

ON THE DEVELOPMENT OF TETRADIUM CELLULOSUM HALL, SP.

By R. RUEDEMANN, Ph. D., Dolgeville, N. Y.

(Plate V.)

The writer found in the Birdseye limestone (lower Trenton) of Ingharm's Mills, Herkimer county, N. Y., a layer of limestone (1½° thick), which consists largely of a fossil described by Prof. James Hall‡ as *Phytopsis cellulosum*. The occurrence of the fossils in the neighborhood of banks with carbonaceous "birdseyes" (described as *Phytopsis tubulosum* in the same paper) and the apparent cellular structure in transverse and longitudinal sections, on account of the septal partitions and tabulæ, invited the above identification at a time when the genus *Tetradium*, though already created by Dana, was not yet well known; no species of it having been described.

The material from Ingharm's Mills is so well preserved that it at once shows that the fossil belongs to the little known and interesting genus *Tetradium*, Dana, of the tabulate corals and, therefore, should be identified as *Tetradium cellulosum* Hall, sp., which name it also bears in the catalogue of Prof. Hall's collection. A figure given by Prof. Hall well illustrates that this species does not grow in compact masses like most other species of *Tetradium*, but possesses a cespitose, dichotomously branching corallum. This mode of growth, however, gives an excellent opportunity to study the

*Man. Geol., 4th ed., pp. 634 and 637.

†Intro. to Geol., p. 409.

‡Nat. Hist. of New York, part VI, Palæontology, vol. I, p. 39, 1847.

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development of the corallites by successive sections and thus removes some of the doubts which, judging from the literature on that genus, still exist.

A short review of the literature will best show what relations of the genus are so insufficiently known that they have been made the special subject of research by the writer.

Dana*, having used a fossil from an unknown locality, characterized the genus as follows: "Corallum massive, consisting of 4-sided tubes, and cells with thin septa or parietes; cells stellate with four narrow laminæ," which characterization enabled Prof. Safford to discover the coral in the Ordovician of middle Tennessee. Prof. Safford, for the first time, gave a full description of the genus, which he placed among the tabulates, and described several forms.† The most important of his observations for our investigation are the following: The tubes are most frequently united throughout laterally, forming massive coralla. The increase appears to be by division of the tubes, the latter splitting sometimes into two cell-tubes, not infrequently perhaps into four; opposite laminæ united form the new walls of the young cells, each of which is in the meantime supplied with its four rays. These rays, however, were regarded by Prof. Safford as not solely serving the process of fission, but also as being of the character of septa, as the following quotations show: "This group we regard as being allied in some respects to the *Favositidæ*, while on the other hand, the cruciform arrangement of the lamellæ unite with the *Zoantharia rugosa* of MM. Milne Edwards and Haime; in fact it appears to afford an interesting type of the quadripartite character of the lamellæ, first pointed out by these distinguished authors in many palæozoic corals." And in the description of *Tetradium fibratum* Saff., it is said "The four lamellæ, distinct, nearly reaching the centre of the tubes."

Prof. G. Rominger,‡ ten years later, shows by a remark of his that he had recognized the fission of the corallites of

*U. S. Exploring Expedition during 1838 to 1842 under command of Charles Wilkes, vol. VIII, p. 701.

†J. M. Safford; Remarks on the genus *Tetradium*, with notices of the species found in middle Tennessee, Am. Jour. Sci., vol. 22, 1856, p. 236.

‡Observations on *Chætetes* and some related genera, Proc. Acad. Nat. Sci. Philadelphia, 1866, p. 113.

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Tetradium into four parts. He writes: "I know of only one fossil resembling *Chætetes*, in which the tubes are multiplied by division, this is the genus *Tetradium*, whose tubes regularly divide into four parts."

Later Nicholson* had repeatedly occasion to study the fossil and to discuss its affinities.

In his excellent manual the characters of *Tetradium* are especially clearly set forth as follows:

"This small family includes only the single genus *Tetradium*, which so far, has only been detected in the Ordovician rocks of North America. In this genus the corallum is massive, and is composed of long prismatic and closely contiguous corallites, which are of small size and have imperforate walls. The tubes are furnished with longitudinal inflections or plications, generally four in number in each tube, which do not reach the centre of the visceral chamber, and which give a characteristic cruciform or petaloid aspect to cross-sections of the corallites. These longitudinal plications are apparently to be regarded as of the nature of septa or pseudosepta. *Tetradium* appears to be related to *Halysites*, but its true affinities and zoological position are uncertain."

The following points in this description are of especial importance to us: Nicholson expressly states that the plications do not reach the centre and therefore are not to be compared to the longitudinal partitions projecting into the visceral chambers of the corallites of *Chætetes*, which indicate the incompleted fission of the tubes, but that they are to be regarded as septa or pseudosepta.

Further, Nicholson had observed before† that the corallites are "in close contact, but not amalgamated by their walls" and that, hence, a double wall is observable.

These observations induced him to consider *Tetradium* as not so closely related to *Chætetes* as its habitus would indi-

*(1) H. A. Nicholson and Rob. Etheridge; On the genus *Tetradium*, Dana, and on a British species of the same, in Ann. and Mag., 4th series, vol. XX, 1877.

(2) H. A. Nicholson and Rob. Etheridge; A monograph of the Silurian fossils of the Girvan district in Ayrshire, fascicle 1, 1878, p. 29.

(3) Nicholson; On the structure and affinities of the tabulate corals of the Palæozoic period, London, 1879.

(4) All. Nicholson and Rich. Lyddekker: Manual of Palæontology, 1889, p. 340.

†Compare his papers on the Silurian fossils of the Girvan district and on the structure and affinities of the tabulate corals, etc.

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cate, but to place it rather near the *Halysitidæ*, a view which had also been suggested by Safford.*

Nicholson discusses the position of *Tetradium* among the Tabulata more fully in his paper on the genus *Tetradium*, Dana, etc., where he writes:

"Amongst the other groups of corals which have been generally referred to the miscellaneous division of the "Tabulata," it is difficult to find one to which *Tetradium* could be referred with entire propriety. - - - With the *Halysitidæ* the genus has some decided affinities, which are increased by Prof. Safford's observation that the corallum sometimes resembles that of *Halysites* or of *Syringopora* in form. We have not, however, noticed this mode of growth in any of the specimens which have been examined by us, and the corallum in general is quite similar in form to that of the massive species of *Favosites* or *Chætetes*. Under any circumstances, should the genus be ultimately referred to this family, it will be in the immediate neighborhood of *Halysites* itself that it must find its place. - - - The only other group that needs consideration in this connection is that of the *Chætetidæ*. In general form and appearance there is the closest possible resemblance between the present genus and some of the massive forms of *Chætetes* or *Monticulipora*; but the peculiar septa of the former are quite sufficient to distinguish them. - - - Upon the whole, therefore, it is perhaps safest to regard *Tetradium* as an ally of *Halysites*, with some affinities to *Chætetes*, and thus forming a connecting link between the families of the *Halysitidæ* and *Chætetidæ*."

Nicholson's view became the prevailing one, for Miller and Zittel describe *Tetradium* as having four-septa, which do not reach the centre of the visceral cavity and Zittel† places the genus in the appendix, containing "genera from the group Zoantharia Tabulata, E. H., of entirely doubtful systematic position."

In later years, however, Prof. M. Neumayr‡ advanced a different view, viz. that *Tetradium* and *Chætetes* are closely related, that the composition of the walls of *Tetradium* of two lamellæ, which constitutes the principal difference between the two genera, has not yet been conclusively proved,

*Safford (op. cit., p. 236) writes "The tubes are most frequently united throughout laterally, forming massive coralla resembling more or less those of *Favosites* and *Chætetes*; sometimes, however, they are united in single intersecting series, as in *Halysites catenulatus*, Linn., not infrequently too the tubes are isolated, or only united at irregular intervals, thus forming loose, fasciculated coralla resembling certain forms of *Syringopora*."

†Handbuch der Palæontologie, Palæontologie, Bd. 1, p. 619.

‡Die Stämme des Thierreiches, Wirbellose Thiere, vol. 1, 1889, p. 317.

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and that the so-called septa are only incomplete new partitions, because their number is not always four; their form agrees with that of the projections of *Chætetes*; and because the corallites often exhibit long and irregular transversal sections, instead of quadratic ones. "A sure decision on the relationship between *Chætetes* and *Tetradium*," writes Neumayr, "depends principally upon the demonstration of the character of the walls; if the latter are simple, the differences are so small that both genera must be placed into the same family; if the walls are double, *Tetradium* can be retained in a separate family, which, however, must be placed directly besides the *Chætetidæ*."

Lately Dr. F. W. Sardeson* has also expressed his belief, that the "pseudosepta" of *Tetradium* are only fissional partitions.

The opportunity to study the still doubtful character of the "septa" and of the walls, as well as the observation of the mode of formation of the peculiar chain-like arrangement of the corallites, have induced the writer to submit the present paper. The investigation was made by successively grinding off the coralla and by making successive sections of especially interesting stages. The figures are all taken from sections.

The youngest stage which could be obtained is represented in figure 1. The diameter of the corallite is .7 mm. Its most remarkable features are:

1) The very thick walls which strongly contrast with the thin walls of later stages.

2) The complete lack of structure in the walls, which are composed of perfectly transparent calcite crystals, while the matrix consists of an opaque, fine grained calcareous matter.

3) The distinct formation of the laminæ by a plication of the entire wall.

4) The formation of the first two plications in two adjacent quadrants, giving the corallites a symmetrical appearance instead of a regular one. As the irregular course and smallness of the young corallites makes it extremely diffi-

*Ueber die Beziehungen der fossilen Tabulaten zu den Alcyonarien Stuttgart, 1896, p. 346.

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cult to trace them in the hard and opaque matrix, the writer has not succeeded in obtaining other equally young or younger stages and, therefore, has failed in establishing the fact of the symmetrical form of this stage beyond doubt. But the supposition of the symmetrical character of the young corallites is supported by later stages, in which again two adjacent plications appear. (Cf. figs. 8, 9.)

The next two plications grow so fast that they soon attain equal length with the first two and, thus, the characteristic form with four plications is produced. (Fig. 2.) The diameter of this stage is 1 mm.

The four plications gradually extend deeper and deeper into the visceral chamber, until they unite in the centre, dividing the whole into four chambers. Figure 10 represents a corallite shortly before the completion of the fission into four young individuals. As this and all other sections demonstrate (compare figs. 8, 9), two new plications appear between the primary ones prior to the coalescence of the latter. There are, therefore, now twelve plications present, four longer and eight shorter ones, This stage which is especially frequently observable in the older compound coralla, apparently has given rise to the remark, made in some papers on *Tetradium*, that while generally there are four "septa" present, also a greater or smaller number may be observed. As mentioned before, the formation of two plications in adjacent quadrants of these secondary corallites renders the latter also symmetrical. In the majority of corallites there appear prior to the coalescence of the primary plications but subsequent to the formation of the two secondary ones in each chamber two more on the primary ones, thus completing the set of four plications in each secondary corallite. (Cf. figs. 6a, 10.) The formation of the secondary projections by folding is not so distinct as that of the primary ones; it is, however, indicated by the fact that secondary plications of adjacent corallites are rarely continuous, but typically alternating on the primary plications (see figs. 9, 10); it becomes also apparent from the structure of the wall in the original to fig. 16a.

By the coalescence of the first four plications the very pretty and characteristic stage, represented in figs. 3 and 4,

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results. The section of the corallum is subquadratic; the four corallites are of equal size, and the walls are still considerably thicker than those of later stages. The young corallites have a symmetrical section, because the lobes at the angles of the square are, notwithstanding their being oldest, smaller that the others, as if the growth had been checked by the thick common wall of the colony. (See figs. 3, 4, 8.)

The four secondary corallites complete their fission independently of each other. Quite often one corallite will divide long before the others and a corallum with seven corallites will result (fig. 5). This stage with seven corallites is as common as the next stages with 10 or 13 corallites (figs. 6 and 7), where 2 resp. 3 corallites have divided. In the majority of the cases, however, all four secondary corallites divide harmoniously. Sections with 16 equally developed corallites (fig. 8) are therefore hardly ever missed on a chip of the *Tetradium*-bearing bank. The fission proceeds regularly and coralla with 19 and 22 corallites still show distinctly their derivation and the former arrangement of the mother corallites, while exceeding the last-mentioned number the general struggle of the young corallites for space brings about a general displacement of the latter, and renders it very difficult, and often impossible, to find which corallites belong together.

Subquadratic or circular sections of coralla with more than 16 corallites are, however, by far not so common as flat, ribbon-like coralla which consist of a few or even of only one row of corallites. The smallest number of corallites in such flat coralla has been found to be 8, arranged in two rows. Coralla of this composition are extremely common. The tracing of their development by successive sections brought out the fact, that they are the result of a fission of the regularly developed subcircular coralla, which fission begins when the latter have reached the stage with 16 corallites. Fig. 11 represents a corallum of 16 corallites in the act of fission; fig. 12 a later stage of the same.

After the fission of the whole corallum, a multiplication by fission of the corallites, on both ends of the bands, sets in, resulting in branches with shoe sole-like (fig. 13) or dumb bell-

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like sections (fig. 14). The rounded ends may separate in toto (fig. 13) or divide again lengthwise and give off a branch (fig. 14 a). The latter process, which is the more common of the two, together with the fast multiplication of the corallites at both ends of the bands, produces very broad branches, which, however, often contain only two and in some places even only one row of corallites. It is the peculiar appearance of these bands, which, no doubt, has induced some investigators to compare *Tetradium* with *Halysites*. But, as the development of this species shows, the origin of the chain-like coralla of *Tetradium* is very different from that of *Halysites* the former originating from a lengthwise splitting of round coralla, the latter from a continued stolonal gemmation in one direction.

Figure 15 shows that with the development of larger coralla a general and remarkable decrease in the size of the corallites, and a becoming more irregular of the shape of the latter are connected. Sections of younger and older coralla present, on this account, a differing aspect and could easily be mistaken as representing different varieties or even species (compare figs. 15 a and b). In sections of older, massive coralla all corallites are of nearly equal size and their plications of equal length; multiplication by fission, therefore, has apparently been greatly retarded. As only such sections previously came under observation, it can easily be understood why the four fissional plications continued to be regarded as septa or pseudosepta. With the septa of the *Hexacoralla* and *Tetracoralla*, they cannot be directly compared, because they have a different function, serving primarily the multiplication by fission. Neither can the term "pseudosepta," as used by Moseley* for slight plications of the wall of *Heliopora*, which in number and arrangement are independent from the mesenteries, be applied here, for the pseudosepta of *Heliopora* do not develop into fissional partitions and the plications of *Tetradium* are too long to have been independent from the mesenteries.

The nature of the plications, therefore, cannot be used to distinguish *Tetradium* from *Chætetes*, the projections of

*Report on certain hydroid, alcyonarian and madreporarian corals procured during the voyage of H. M. S. Challenger. Voyage of H. M. S. Challenger, Zoölogy, vol. II, 1881.

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which have long been recognized to be the means of fission. Neither can the chain-like arrangement of the corallites be used to compare this genus with *Halysites*.

As a third differential character between *Chætetes* and *Tetradium* the presence of a double wall has been described by Nicholson. Neumayr remarks that this observation has not yet been verified. In fact, only a very small percentage of sections of coralla, in the writer's collection, show any traces of a double wall at all. As the figures 1, 3 and 4, well illustrate, the walls are formed by closely packed, transparent calcite crystals, the outlines of which are indicated in the figures. Sometimes one crystal extends throughout the entire width of the wall. The crystalline nature and the perfect lack of structure in these walls is the more striking, as the brachiopods and bryozoans in the same slides exhibit the finest details of their structure. It, then, would seem, that the walls of *Tetradium* were homogeneous and simple. But as all walls, with the exception of the common outer wall, have been secreted in folds of the ectoderm and hence ,appear as plications of the outer wall (see figs. 1 and 2), it is evident that they must have been double originally. A careful scrutiny of the walls revealed indeed the fact that some sections (cf. fig. 8) possess a dark line extending a short way from the exterior into the plications, thus demonstrating the amalgamated nature of the walls. There have also been found a few specimens (see figs. 16 and 16a), in which a dark median line passes continuously through the walls. It follows a zig-zag course on account of the secondary plications which branch off on alternate sides of the primary ones. A stronger enlargement of the walls shows that the dark median line is caused by the presence of the same organic coloring matter which renders the matrix opaque and which here is deposited in the calcite crystals (cf. fig. 16a)*.

The conclusion to be drawn from these observations is that the walls originally were double, that, however, with very few exceptions, a complete amalgamation took place already in the earliest stages as proved by sections of excellently pre-

*These dark median lines must not be confounded with the fracture-lines running quite regularly in the walls in such sections which have been ground with too coarse emery.

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served young corals (figs. 3 and 4). We have here, therefore, relations similar to those found among the monticuliporoids, where also certain forms possess a distinct dark median line, while in others a perfect amalgamation has taken place. All these observations must teach that it cannot be a question of great systematic importance whether the walls of *Tetradium* are simple or double, and, that the separation of *Chætetes* and *Tetradium* into two families can hardly be founded on this.

To sum up, it may be said that, in the writer's opinion, the nature of the interior processes, and of the walls, as well as the mode of growth of the coralla, proves at least this species of *Tetradium* to be a chætetide and that *Chætetes* and *Tetradium* are only generically different.

Explanation of Plate V.

All figures represent sections of *Tetradium cellulosum* Hall, sp., from the Ordovician (Birdseye limestone, lower Trenton) of Ingharm's Mills, N. Y.

Fig. 1.—Young stage with beginning fission. Magnified 16 diameters.

Fig. 2.—Stage with more advanced fission. × 16.

Figs. 3 and 4.—Corallum after the first fission. × 16.

Fig. 5.—Corallum with seven corallites, resulting from the fission of one of the corallites of the preceding stage. × 4.

Figs. 6a and 6b.—Opposite sides of one section (2 mm. thick). Seen in reflected light. × 4.

6a.—Fission of one corallite nearly completed.

6b.—Fission of two corallites completed.

Fig. 7.—Stage with completed fission of three corallites. × 4.

Fig. 8.—Fission of all four corallites completed. × 4.

Fig. 9.—Corallite with 4 primary and 8 secondary plications. × 16.

Fig. 10.—Corallite with nearly completed fission. × 16.

Fig. 11.—Beginning fission of a whole corallum. × 4.

Fig. 12.—Complete fission of the same corallum. 12a cut obliquely. × 4.

Fig. 13.—Beginning transversal fission. × 2.

Fig. 14.—Longitudinal fission. × 2.

Fig. 15.—Section through apparently intersecting bands of corallites. 15c cut obliquely. × 4.

Fig. 16.—Specimen showing structure of wall. × 8.

Fig. 16a.—The same. Wall enlarged. × 125.

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THE GEOLOGY OF THE ENVIRONS OF ALBUQUERQUE, NEW MEXICO.

By C. L. Herrick, Albuquerque, New Mexico.

(Plate VI.)

It is somewhat surprising that the geology of the valley of the Rio Grande in New Mexico seems to have escaped attention, while the more inaccessible parts of the territory have been the subject of elaborate memoirs. The small area about the metropolis of New Mexico which forms the subject of this paper is not wanting in interest from many points of view, but it seems never to have received more than passing attention, while the large area of the Mount Taylor district to the west is the subject of the interesting and elaborate monograph by captain Dutton.

The area covered by this report is, roughly speaking, a square of twenty miles, with the city of Albuquerque at its centre. Its study has been carried on in intervals of the administrative work of the University and cannot hope to be exhaustive, yet we trust that a foundation has been laid for a more minute study of the valley at other places. The attempt to secure information at second hand has proven futile, for the few who in this region are sufficiently interested to observe natural phenomena are not well enough versed in the elements of geological interpretation to report correctly the facts observed. The writer gratefully acknowledges the assistance of Prof. E. W. Claypole, a former colleague in the geological study of the Waverly of Ohio, who accompanied him upon several of the expeditions upon which this paper rests. Although the conditions here reported are in a sense local, it is upon the accurate comprehension of these details that the intelligent survey of the general geological outlines must rest. A map with contour lines and details of distribution is in process of construction and will be issued in the forthcoming bulletin of the University of New Mexico.

I. The Albuquerque River Deposits.

The valley of the Rio Grande at Albuquerque offers a number of interesting geological problems, some of which when solved may prove of far-reaching importance for the interpretation of the general surface geology of the territory.

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To the east of the city, at a distance of about ten miles, the eastern wall of the valley is formed by a rather abrupt escarpment of gneisses, granites and quartzytes in what may have been the axis of a monocline. Near the base the abrupt ascent is broken by rounded foot hills, and the products of erosion from this granitic metamorphic series are to be found widely distributed in the valley gravels. Respecting the age of this formation it is only known that it is older than the coal measures, limestones of the latter age being everywhere present at the top of the metamorphic rocks.* In some places there are pebbles of granite in the silicious layers at the base of the Carboniferous, and unconformity may be assumed in many places, while the resemblance of the silicious strata interbedded in the limestones to the upper parts of the metamorphic series and the lack of apparent unconformity in some places suggests that the interval may not have been so long as has been supposed, or may occur lower in the series—a suggestion also made possible by the occurrence in the same relative position in the granite series at Limitar (fifty miles south) of a band of fossiliferous limestones at a depth of several hundred feet below the lime beds of undoubted Carboniferous age. The metamorphic series east of Albuquerque rises in places to a hight of 2,000 feet above the mesa or 300 feet above the river at the city. The dip is a few degrees (15-25) to the east, so that the irregularities of erosion as well as the varying amount of uplift brings the Carboniferous beds at some places much nearer the mean level. If the mesa east of the river is really in the axis of an anticline, as has been suggested, it must be admitted that the western wall has been entirely removed at this place. If, on the other hand, the fold was a monocline the whole western portion has been faulted hundreds of feet below the river level. Nearly opposite Albuquerque the river gravels are much obscured by sand drifted from the mesa to the westward which is underlaid by sands of a relatively late period (Cretaceous).

From five small volcanic cones a small sheet of basaltic lava has spread over an area of about twenty-five square miles with an irregular front upon the river of about five or six

*We have been unable to verify the reports of fossils older than the Carboniferous in any part of the Rio Grande valley.

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miles. Along this river front the basalt varies from six to twenty feet in thickness and is quite vesicular, especially at the top, and it reposes on substantially horizontal beds of sandstone of the same age apparently as that forming the mesa back from the river, though there are one or more benches of river drift nearer the river. So far as seen, the material capped by the basalt does not contain the trachyte, andesyte, rhyolyte or basaltic pebbles occasionally found in the river drift, though it contains quartzyte and limestone fragments and also fossil woods. This point is worthy of careful study, for by this means it may yet prove possible to ascertain the age of the eruptives which are so characteristic of the region further north and south. At any rate, the evidence so far at hand seems to indicate that the lava flows here are older than the river gravels, since we have yet to find a place where the lava overtops the fluviatile formation, while near Isleta we do find the river gravels overlying the basaltic flows. Much depends upon the correct estimation of the age of these lava flows, inasmuch they are said to cover ancient pueblos, and in some cases maize has been found in a charred state below the lava. Near Isleta, an Indian pueblo about twelve miles south of Albuquerque, there is another such a flow and the underlying sandy layers have here been greatly indurated and reddened. In this case there are at least fifty feet of the Cretaceous (?) sandstones and shales below the lava, but the elevation is not uniform, so that near the southern edge the lava—there only about eight feet thick—is covered in places by the river gravels.

Near the northern end of this flow there is an insular patch of the lava cut off from the main flow by a narrow valley of erosion which must have been at one time the channel of the river or an arm of it, and this at a time when the river was somewhat higher than at present.

These facts with others, the details of which need not be given here, make it apparent that the local basaltic lava flows have occurred at a date more recent than the Cretaceous deposits beneath them and at a period earlier than that of the river gravels. Whether the latter are of approximately Champlain age or not must be left to the future to determine, but it is a matter of no small interest to ascertain the age of

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the several eruptives more definitely in view of the relation already noted with human remains preserved beneath them. The possibility that these isolated flows may differ greatly in age is not to be forgotten, though the essential lithological and structural similarity of the rocks as well as the similarity of the methods of occurrence suggest a close agreement in age.

Having thus briefly indicated the environs or limits of the river deposits we may turn our attention to the latter as they are represented at Albuquerque. These beds are exposed at various points in the immediate valley of the present river. The banks formed by the erosion of the older flood plain are often as high as seventy-five feet above the present river bed below the city. This plain is a large mesa extending from the bluffs to the foot hills on the east and the surface is nearly flat but with a gentle upward slope to within a short distance of the mountains whence the inclination to the base is more rapid. The uppermost of the deposits of this mesa and that which lies at or near the surface where un-eroded is a curious yellowish-white marl, which is apparently about six feet thick and can be traced at about a constant level in the immediate river bluffs to a point south of Isleta, as well as north to Albuquerque and eastward to within a mile or two of the base of the mountains. South of the arroyo formed by the outlet of Tijeras canon in the Sandias the mesa is immediately underlaid by this deposit so that it is thrown out by burrowing rodents. A curious feature of this plain is the occurrence of numerous slight depressions thickly distributed over the area. These are rarely more than five yards across and commonly are from eighteen inches to two feet deep and are provided with a raised border. They might be taken for buffalo wallows were it not for their great abundance and general distribution. These depressions seem to hold water as they sink to the level of the marl. This marl, which may henceforth be known as the Albuquerque marl, has been detected on the western side of the Rio Grande as far south as Belen, thirty miles south of Albuquerque. The composition of the marl is largely calcareous, though it contains small pebbles also. Near the city there has been so much erosion that its horizon could not be reached for some distance beyond the

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University campus, but further south it is quite conspicuous as a white band near the summit of the bluffs for many miles. The following is the partial analysis made by Prof. R. W. Tinsley, chemist of the university.

SiO_2	26.53
Fe_2O_3	1.20
$CaCo_3$	64.47

It will be a matter of considerable local interest to determine the conditions under which such a marl could have been formed. If one could find evidence of a dam below Albuquerque, which at the time when the flood plain had reached its highest point could have formed a great lake or estuary, it could be supposed that highly carbonated water from the limestone areas to the east may have spread over the bottom this rather uniform layer of calcareous material. The formation of such lakes or quiet spots on a small scale in the river valley has other illustrations. Or one might be tempted to think of wide-spreading flows of volcanic waters charged with a material sedimented out on cooling. That the marl is not a purely local deposit is proven by its occurrence on both sides of the river.

Beneath the marl is a considerable band of gravel and rounded stones of variable size. The materials are chiefly quartzytes, gneisses and granites, evidently the debris from the metamorphic series already mentioned, though fragments of andesytes, trachyte, rhyolyte and basalt are also found. In some places the gravels on the east side of the river contain scoria and basalt evidently of the age of the recent cones of the west side of the river, suggesting an extension of those flows to the east of the present river. And as fragments of petrified wood occur with them we may also conclude that the underlying materials in this place were of the same age as where exposed elsewhere,—namely Cretaceous. The thickness of these gravels may vary from two to twenty or more feet. Beneath these appears a sandy loess passing into clay sometimes carrying fragments of undecayed wood. The depth of this stratum is as yet but imperfectly known, but it is eminently characteristic and may be recognized everywhere in the immediate bluffs of the river. In some places it has a

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clayey consistency, while more often it is composed of fine grains of sandy material. About Albuquerque it is in request as a "molding sand," for which purpose it is well adapted. It is plain that this series, which we shall designate as the "*Rio Grande loess*," must have been deposited during a period of abundant but sluggish flow. The great extent and the horizontality of the series afford proof of these suggestions. The loess seems to repose upon the Cretaceous of the immediate valley of the river. The original inclination of the valley must have been greater than at the close of the loess period, for only ten miles above the city of Albuquerque the obliquely tilted sandstones of the Cretaceous appear in the river bed. It appears probable that in many places at least there is a stratum of coarse material between the loess and the bed rock, though the only direct evidence we have is from the reports of well-diggers who report a stratum of "cobble stones" as the water-bearing horizon at a depth of 350 feet upon the mesa three miles east of the University campus. It may be assumed that the river silted itself up during the period of quiet represented by the loess. If so, the re-excavation of the channel must have followed immediately, for, as above stated, the next number of the series, the "*Rio Grande gravels*," is an exceedingly variable quantity. It is a coarse or moderately fine deposit of the most diverse materials. Among these the granitic and quartzytic fragments from the neighboring mountains may be said to predominate, yet there are localities where the entire deposit is composed of volcanic scoriæ. In a previous paper the writer has described the instance further down the river where an isolated basin has been filled with floating pumice, which deposited by its own abrasion the so-called Socorro tripoli. A somewhat similar instance has since been found about nine miles north of Albuquerque where a large deposit of the same character may be seen from the train. Large quantities of the dark basalt of the local flows along the valley are noticed everywhere in these gravels together with rounded fragments of andesyte and trachyte derived from the older eruptives penetrating the stratified series of the valley margin. The upper surface of the loess is everywhere deeply eroded and in the irregularities so produced are deposited the coarser elements of the gravel.

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FIG. 1. An exposure in the suburbs of Albuquerque showing the eroded upper surface of the Rio Grande loess with the irregularly banded gravel reposing upon it.

Fig. 1 illustrates such an instance in the banks whence molding sand has been removed at the eastern end of Lead avenue in the city of Albuquerque. Not only are the deposits of gravel very irregularly distributed, but it appears that they are mostly collected in the centre of the valley or near the present river bed. It would seem safe to assume that these gravels represent a torrential period in the history of the river and that accordingly this was a period of active erosion, of numerous changes in the river, and corresponding irregularity of deposition. The river must have stood at times at a high level, and it may be that this was a time of breaking away of old barriers. The loess must have been high enough to have caused the river to flow over some of the recent lava sheets of the valley, as is shown by the abandoned channels at various places in the lower course of the river. In fact, one is almost irresistibly reminded of the conditions in glaciated regions, where old river courses are continually being revealed. Yet in these cases it would seem that the direct agency of ice is excluded. One such instance is to be described beyond, while a still more extensive occurrence in the neighborhood of La Joya may form the subject of a later contribution. It was at first thought that the river had been dammed at these points by flows from the adjacent craters, but as further examination seemed to show that the flows were older than the loess and certainly older than the gravels which are, in places,

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found reposing on the top of these flows, and as it seems necessary to seek some explanation of the superposed marl, we must probably look for some later agency to account for such dams. Perhaps flooded conditions of affluents below may give us the clue. It will be necessary to correlate the above described facts with the conditions existing in the headwaters of the Rio Grande before all the elements in the problem can be fully understood, yet it is not hard to see that in a general way the record is of a river whose upper tributaries were under the influence of the permutations of the Glacial period.

II. The Isleta Volcano and the Paria Mesa.

In the valley of the Rio Grande in New Mexico is situated the ancient pueblo of Isleta, well known through the writings of Lummis, who lived there for some years while studying the native races. This village is about twelve miles south of Albuquerque in the flood plain of the present river, above which it is raised upon what may have been a natural eminence of no great hight but which has been added to by accumulations of unnumbered generations. Although the pueblo is modernized to a great extent it is still inhabited by the same race as at the earliest known date, and these Indians eke out their livelihood, derived from the fields and orchards in the vicinity, by the sale of pottery and trinkets which the squaws offer to the travelers on each passing train.

It is not with the village nor its inhabitants that this paper is concerned, but rather with the interesting geological environs. The Rio Grande is now a sluggish stream as muddy as the Missouri and nearly as changeable within the narrow limits of the recent gorge. But the valley is full of evidence that the river was not always the comparatively tame and ineffectual irrigation purveyor it now appears. The description of the valley deposits is given elsewhere, and it is only necessary to say here that the broad valley was at one time filled to the hight of about 350 feet above present water level, and data are yet wanting to indicate how much deeper fluviatile deposits may extend. At least three divisions in the river bluffs have been identified. The base of this "Rio Grande series," so far as known, is a thick bed of loess or fine detritus

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of a yellowish color and containing few large pebbles, but a larger number of what seem to be fragments of granitic debris. The upper portions especially contain numerous white chalky grains that may be simply the kaolinized remains of the feldspathic fragments. Although the oldest of these beds, the loess nevertheless contains fragments of unaltered wood in some places. The upper surface of this Rio Grande loess is irregularly eroded and upon this eroded surface there reposes a layer of shingle pebbles of considerable though indefinite thickness. It may be roughly estimated at an average of twenty-five feet. The upper part of this bed of Rio Grande gravel is variable in nature, but everywhere in the vicinity of Albuquerque where the uppermost deposit is preserved it is found to support a band of white chalky material which we shall call the "Albuquerque marl."

The present gorge of the Rio Grande in the vicinity of Albuquerque is not more than two or three miles wide in most places and this small flood plain is dotted with ranches and villages. From the west at several places the flood plain is encroached on by abrupt lava-capped bluffs. One such is adjacent to Isleta and extends from a point just west of the pueblo for three to four miles northward. The first thought is that the flow forming the cap has taken place since the river gravels were deposited, for the material covered is a sandy and horizontally stratified deposit not unlike the finer forms of river detritus. The source of the lava, which is a black, rather vescicular basalt, is near at hand, being a small volcanic cone about three miles northwest of the pueblo and not more than three to five hundred feet above the water level of the river. The eastern wall of the crater has been broken away and the latest flow has accordingly been toward the sea, in which direction it may at one time have extended in long radiating streams from the main sheet as far as the present river bed, though these outlying portions have long since been carved down by the river and only great piles of debris remain, and the greater portion of this material is doubtless buried beneath the sands. The bluff remaining looking toward the river, is exceedingly irregular, but in hight is quite constant, being about 100 feet at the portions lying to the north but sinking to less than thirty at the southern limit.

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The north and south length of the area is about three or four miles and the greatest thickness of the lava is not more than twenty-five feet at any point seen, though the thickness is not at all constant, but in some places is reduced to four or five feet. The appearance of the upper surface shows that there was not a single wide-sweeping flow, but a somewhat intermittent series following in such a way that the older flows were in some cases overtopped by later discharges of the same material. In composition the lava is apparently exactly like that of the entire series of recent basalts of New Mexico, which will form the subject of a separate paper. A few miles further west is a second larger cone, the flows from which may prove confluent with that of the one now under consideration on the west. It is noticeable that these recent cones tend to be clustered in groups. The present group may be known as the Isleta group, comprising an east and west Isleta peak. It lies about ten miles south of the Albuquerque group. But the interest which attaches to this flow is quite apart from the character of the lava itself. As already indicated, it would not be unnatural to infer, in looking at the deposits as they lie in the valley apparently parallel to those formed by the river to suppose that these two are essentially the same—fluviatile sand and gravel accumulated by the river at a time when it was larger than at present, or when its bed was less inclined toward the south. If this were the case it would follow that the lava flows might be comparatively recent and such vestiges of man as might be found beneath the lava need not be assigned any great antiquity. But a brief study of the sub-igneous deposits in the Albuquerque group of cones seemed to point to a quite different conclusion. If they were really fluviatile these deposits were not a part of what has been called the Albuquerque series, for they are of a different lithological character. In the modern river gravels the pebbles are of gneiss and granite as well as quartzyte, but in addition contain great numbers of fragments of andesyte, rhyolyte and trachyte, i. e., of materials such as are found in the older eruptives of the valley. So far, these last-named elements have not been found in the sub-igneous deposits mentioned, but fragments such as may have come from the Cretaceous of the region to the west, if not of that age

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themselves, are commingled with the granitic debris. But in the midst of the perplexity growing out of the evidence that the river erosion of the time when the present gravels were deposited has involved these lava-topped bluffs, the study of the material below the lava of the Isleta cones has offered an unambiguous solution of part of the problem. At that place indeed the recent river gravels (No. 2 of the Albuquerque series) are in places to be seen actually overlying the lava and forming extensive beds upon its surface. On the other hand, as stated elsewhere, fragments of the lava and of pumice have been found in No. 2 on the opposite side of the river, An examination of the materials below the flow at Isleta shows that they are largely composed of sand grains of apparently granitic origin. They are mostly quite fine and only rarely do large pebbles occur. Close inspection shows that in many places there is a large admixture of small black grains of a rather obscure nature. Fortunately a place was found at a point nearly due east of the crater where the whole matter is explained. Here the thickness of the underlying gravels is exposed for about fifty feet, and the lava is very irregular. In some places it is fifteen to twenty feet thick and in an adjacent part it is less than five, while in other places the lava never has flowed over the gravel beds. The latter, in those portions in which they are, or have been, covered by the lava, conforms to the irregularities of the under-surface of the flow so that, as the deposits are very clearly and minutely stratified, there is no question of erosion prior to the flow sufficient to account for the irregularities. Different parts of the stratified gravels are unconformable to each other, as might be in a current of changeable character with great burden of detritus. But the clue to the nature of these deposits is found in the fact that in the midst of this stratified deposit and scattered through it from top to bottom of the entire exposure are large angular blocks of basalt quite like the material of the flow and varying in size from the diameter of one's head to that of a pea, arranged irrespective of stratification, though in some places there are bands filled with small grains of a similar character. The appearance of the exposures is curious in the extreme for the mass is so minutely stratified and its materials so plainly the detritus of sedimentary deposits that the

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agency of water is proven, while the arrangement of the angular blocks is like that of glacial boulder clay. The inclination of the strata is slight but obviously in a direction radiating from the cone of eruption. It would be natural to think of volcanic ash or mud but the materials do not admit of this conclusion. We are shut up to the view that at the time immediately prior to the last eruption of the Isleta crater there was a great out-flow of water from the crater, accompanied by explosive fragmentation of pre-existing lava whose pieces were either intermittently thrown from the crater to be lodged in the pasty mud hurried along by these flows, or caught up in the current and after lodging by their own weight, finer material was settled about them in the process of sedimentation. This mud-flow evidently extended beyond the subsequent flow of lava, for such banks are exposed with their freight of lava blocks but without the settling and distortion resulting from the weight of the lava. Incidentally it may be learned that the lava flow followed soon after the water, for it can easily be seen that the weight of the lava caused great displacement, especially near the edge where the still pliant material was squeezed beyond the edges. The upper surface of the sand is baked and browned more than in other places, and a great deal of silicious matter has been incorporated into the under layers of the lava, thus proving the presence of water at the time of the flow. The finer particles of basalt were, of course, carried according to the same law as the other ingredients of the material caught up by the gushing waters. Much yet remains to be done in ascertaining the extent of the deposits from such floods. That the quantity of water must have been enormous is plain when we note that nearly a hundred feet of the material certainly was deposited over many miles, while the actual thickness may have been much greater. (Figs. 1, 2 and 3.)

This instance has a special significance in establishing the fact that in connection with the lava flows of the basaltic series there occurred great floods of hot water which may well have been highly charged with gases and silica. Thus it seems possible to account for the great areas covered with silicified wood in the western part of the territory and Arizona. Such great floods would undoubtedly produce lakes of silicious

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FIG. 2. The Isleta volcano. In the middle ground the abrupt escarpment of the lava-topped mud flows from the volcano.



FIG. 3. Portion of the same as shown in figure 2 to show the fragments of basalt scattered in the stratified mud.

water in which trees might become impregnated with silica, or more probably a mass of such pasty material charged with silicious water would be a still better means of altering imbedded trunks. Of course, the age of these flows is still to be determined, though it may safely be placed at an earlier period than that in which the river gravels were deposited, that is, earlier than the post-glacial or Champlain period. It would appear that the silicification of the forest beds must have been in a general way contemporaneous with the sand accumulations, but the trunks are sometimes found in sandstones supposed to be not later than the Cretaceous. Still further, the finding of ears of corn imbedded in the lower surface of the flow of lava in certain places might then be thought to take human occupation back to that period, but it is plain that at present no such wide generalization is warrantable, though the above-mentioned facts point the way to the final

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settlement of the larger question as to the age of man in New Mexico.

The Paria Mesa.

In connection with the flow at Isleta above described, another problem is to be noticed. About two and a half miles north of Isleta a part of the lava-topped mesa extends far out into the valley. It is here nearly one hundred feet high, though the lava is rarely more than ten to fifteen feet thick. (Fig. 4.) The talus is very steep. This area of about

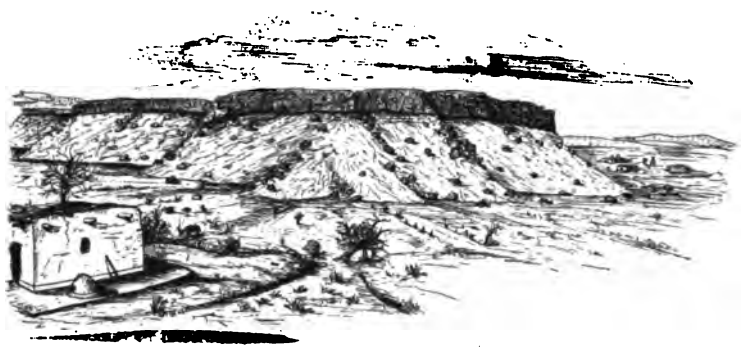


FIG. 4. The Paria mesa. The old river channel is to the left.

one quarter mile in length and a little more than one-half that in width has been cut off from the rest of the area by what must have been an arm or old channel of the river at its highest. This cut-off is nearly north and south in its course and is blocked at its northern end by bars, part of which may be due to drifting sand and more to bars accumulated when the river swept in an arch near the entrance, as there is evidence that it did at no very remote period. The bluffs of the western bank of the river are here a considerable distance further west than the opening of the old channel, and there are remnants of both the loess and the gravel deposits, i. e., numbers one and two of the Albuquerque series. Similar gravel is found on the summit of the mesa. Near the northern end of the old channel is the small village of Paria, and the town is supplied from rather shallow wells, showing the existence of the river channel at that place. This ancient channel raises the interesting query as to the conditions which could have

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resulted in so blocking the main channel as to cause the stream to cut through this solid mesa. May it have been that the flow of mud due to the water from the volcano dammed the stream and caused this side erosion, or, what is more probable, that the filling up of the old valley by the loess and then the gravel lifted the level of the entire valley so high that the water found its way over the lava area and then, when the gradual removal of the glacial detritus below reduced the level, the water wore through this sheet of lava and excavated the new channel before that removal had opened up its old channel.

In this connection it may be noticed that upon the summit of this insular mesa there is what seems to be the remnant of an aboriginal fortification consisting of two walls of stone meeting at a right angle to the northwest, the longer extending south about 100 yards, the other east about seventy-five yards. At present the walls are loose ridges of lava blocks about six feet high and ten to fifteen feet wide. There is some evidence that the ground on the inside near the wall has been excavated several feet. The outline of only one pueblo of small size could be seen within the area thus partly protected, though chipped flints and potsherds are numerous. It seems hardly likely that the embankment was raised against water, and, in fact, there is at the angle an opening in the west wall like that of a sally port or door. The basaltic walls of the mesa and fragments at its base are covered with aboriginal tracings in which the figure of the turtle and the four pointed star seem predominant.

III. The Bernalillo Volcano.

The town of Bernalillo is sixteen miles north of Albuquerque on the east bank of the Rio Grande. At this point the Cretaceous emerges boldly from beneath the river gravels and loess. All the river deposits betray the influence of the Cretaceous below some time before the latter actually outcrops. Opposite the town and for some miles to the northward the river is bordered by long horizontal bluffs capped by basaltic flows of no great thickness, but of many miles extent. These bluffs afford the most instructive illustration of base-leveling that could be imagined. (Fig. 5.) The basalt re-

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FIG. 5. More distant view of the neck of the Bernalillo volcano and the lava-topped mesas beyond.

poses on the red and grey Cretaceous strata, which remain nearly horizontal. The sources of these flows is not difficult to locate in local craters which penetrate the Cretaceous at various places. The erosion of the river has done a very useful service to the geologist, in removing, to a large extent, the soft strata about one of the old cones and exposing the true inwardness of the eruption when occurring in soft materials. In fact, it may be said to afford the necessary supplement to the data from the Isleta volcano. Here, as in that case, the lava forced its way through the soft Cretaceous strata, and here also the outbreak seems to have been attended with a great flood of hot water which has redistributed the materials. In one place (Pl. VI., Fig. 1) erosion has exposed the "neck" or original column of lava which cooled in the throat of the crater, and one may see the long dykes of basalt radiating in various directions into the soft displaced sand (Pl. VI., Fig. 2). These radiating dykes formed ribs to which the plastic sand mixed with fragments of the basalt adjusted itself. In the vicinity of these dykes there is often a small amount of metamorphism roughly proportionate to the thickness of the intruded mass. There is much reason to suppose that the other volcanoes of the valley are not later than these mentioned.

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In the immediate environs of Albuquerque there are no complete exposures of the Cretaceous, but at a point on the west side of the Rio Grande about three miles northwest of the bridge at Los Corrales there is a fairly good continuous exposure of sands and marly lime referred to this period. The rock is very slightly coherent—scarcely more than a crag—and occurs in bands of red, yellow and white, while near the top is a narrow band of lime containing some imperfect remains which have not yet been studied. The entire thickness exposed is rather over one hundred feet, of which the lower half is of red sand with nodules of greater consistency. Some layers are quite firmly cemented. Near the top of the light-colored division the sand is loose and contains numerous pebbles of red and black chert, quartz, quartzyte and other materials apparently of granitic origin. It appears that this Cretaceous series is the country rock back from the river and that it has furnished a large part of the materials for both the older and the more recent river deposits. The valley nearer the river at this point is filled with materials similar to the portion about Albuquerque, the loess being below and overtopped by coarser material deposited on the eroded surface of the loess in sand-bar formation of the most interesting sort. Prominent among the coarser materials are fragments of basaltic lava evidently derived from flows higher up the river. No such material is seen in the Cretaceous gravel beds. Respecting the latter it may be noted that these beds are similar to those occupying the hills northeast of Socorro, where they are conspicuous by reason of their colors and stratigraphic distinctness.

IV. The Albuquerque Volcanic Group.

A good illustration of the circumscribed lava flows from the latest eruptive cones is seen about six miles west of Albuquerque. Here five small cones rise in a group from the western crest of the valley. The axis of the group is north and south. Each cone may be the core or plug of the original crater, but, in that case, the walls of the crater proper have disappeared. It is claimed that there are evidences of local heat and vapors, but of this we have no evidence. The lava is a black vesicular basalt, and it extends in all directions,

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but especially to the east and south in an irregular sheet for several miles. Probably the greatest extent is not more than five miles from the cones, though the abrupt face as seen from the river is probably six miles long. The inclination of the flow is slight, not over two or three degrees, and at the exposed margins the thickness is often less than ten feet, though at points nearer the cones the thickness is somewhat greater. It is a matter of some surprise that so thin a flow should have proven so long fluid as is implied by the great extent of nearly level country covered. In some places the river has exposed a nearly perpendicular bluff over fifty feet high capped by this flow, and with the sides and base protected by the angular blocks. Along the southern face, on the other hand, the slight erosion of arroyos has served to expose the underlying strata of sand and gravel without having displaced much of the lava, as is proven by the relatively limited talus and the uncovered strata of adjoining hills. These strata differ from the recent fluviatile deposits in appearance and contents. The upper portion is but slightly indurated and the pebbles included in it are largely quartzyte, chert and lime. The beds are horizontal but differ from those nearer the river which contain materials like those which are derived from the granites and gneisses of the Sandias to the east. Fragments of silicified wood occur in the beds covered by the lava. They may, therefore, be of Cretaceous age, though it will be an interesting problem to determine whether the flow at other points did not run over the river gravels.

[European and American Glacial Geology Compared. VI.]

THE MECKLENBURG OR BALTIC MORAINES.

By Warren Upham, St. Paul, Minn.

Ridged and hilly marginal drift accumulations, extending in a curved and looped course, form the most conspicuous topographic features of Denmark and northern Germany. The belt which bears these drift hills, partly in a single series, but in other parts comprising several approximately parallel or interlocking series, was traced along its entire extent through Germany by Prof. R. D. Salisbury in 1887, who first

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recognized it as a terminal morainic belt, similar to the terminal moraines of the northern United States.* This most prominent European moraine series reaches nearly 300 miles from north to south and southeast in the peninsula of Denmark, Schleswig, and Holstein; and thence it continues eastward about 500 miles in broadly crescentic loops, passing through Mecklenburg, Pomerania, and West and East Prussia. Its course in these German provinces, to the Russian frontier, as outlined by Salisbury, has since been in part fully explored and mapped by Wahnschaffe, Keilhack, and other German geologists, especially for distances of 50 or 60 miles both to the west and east of the river Oder. Immediately eastward of that river, a great moraine loop incloses the southern and eastern sides of an area of most remarkably abundant drumlins.†

On account of the general parallelism of this moraine belt with the coast of the Baltic sea, and because its drift was transported by an ice-sheet flowing across the Baltic basin toward the west and south, it is commonly called the Baltic ridge. From its good development in Mecklenburg, Prof James Geikie has applied the name Mecklenburgian to the epoch or stage of the Glacial period when its morainic drift was amassed.‡ In North America a correlative and probably contemporaneous stage of glaciation produced the great series of moraines which has been mapped from Nantucket and Cape Cod to Wisconsin, Iowa, Minnesota, the Dakotas, and the Canadian provinces of Manitoba and Assiniboia. The Late Glacial time of accumulation of these moraines had been somewhat earlier named by Chamberlin the Wisconsin epoch or stage;§ and this term, as I have shown in a former paper,‖ may be better used, in accordance with the law of priority, for the moraine-forming stage of the Glacial period in Europe as well as in America.

My first observation of the Baltic ridge last summer was

*Am. Journal of Science, third series, XXV, 401-407, May, 1888.

†Noticed in my third paper, Am. Geologist, XXI, 237, April, 1898.

‡Journal of Geology, III, 241-269, April-May, 1895.

§Chapter XLII in Geikie's Great Ice Age, third ed., 1894; Journal of Geology, III, 270-277, April-May, 1895.

‖Am. Geologist, XVI, 100-113, August, 1895.

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on the railway route from Hamburg to Oldesloe, Lübeck, Kleinen, Bützow, Rostock and Warnemünde, passing through Holstein and Mecklenburg on the way to Copenhagen and the Scandinavian peninsula. Again, returning from Göteborg (Gothenburg) I crossed the northern part of the Kattegat to Frederikshavn, the most northern port of Denmark, and examined the moraine belt in its fine development near that town. Thence it was observed from the railway in passing west to Hjörring and southward through the whole length of this peninsula.

From these observations it appears certain that the Baltic ridge was formed when the border of the European ice-sheet rested on the eastern part of Schleswig and Denmark as far north as Frederikshavn, being there indented by a great re-entrant angle, from which the ice-front extended westward, resting on the northwest coast of Denmark, and thence probably extending southwesterly across the area of the North Sea. On the east coast of Yorkshire in England an apparently correlative moraine, described by Prof. H. Carvill Lewis and by Mr. G. W. Lamplugh, is well defined along a distance of about seventy-five miles northward from the mouth of the Humber, past Bridlington, Scarborough and Whitby, formed by an ice-sheet which spread from Norway and Sweden across the North Sea basin. In England and in continental Europe alike, as also in North America, wide areas of glacial drift lie outside the moraines, reaching south nearly to the Thames at London and to Brussels and Dresden. In America neither the maximum Kansan extension of the ice-sheet, nor, after an interglacial retreat, its second great Iowan advance, was notably attended with moraine accumulation; but, during the ensuing Wisconsin or Champlain epoch of final recession, many conspicuous moraines, like these west and south of the Baltic and others farther north in the island of Seeland, in Sweden, and in Finland, were amassed at many lines where peculiar conditions of the waning ice-sheet favored the deposition of much marginal drift.

Prominent moraine hills rising 100 to 150 feet above the adjoining country, to altitudes of 200 to 300 feet above the sea, extend fifteen miles from the coast of the North sea at Lönstrup east by Hjörring to Sindal. Thence southward

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thirty miles to the Limfjord at Aalborg, moraine drift covers the eastern half of this northmost part of Denmark, its highest hilltops being 300 to 440 feet above the sea level. The northeast boundary of the moraine belt is about two miles southwest of Frederikshavn, at a hight of about 100 feet; and within a mile farther southwest one ascends 200 feet, or more, upon typically morainic, irregularly grouped hills of till, containing abundant boulders, many of them granitic, up to three feet and occasionally five or six feet in diameter. As the underlying formations of Denmark comprise only Cretaceous and Tertiary strata, the granitic boulders are known to have come from the great Archæan region of Sweden and Norway. The contour of these hills and of all the country within the view for many miles westward and southward is wholly morainic, presenting a multitude of irregular hills and ridges, which rise generally forty to seventy-five or one hundred feet above adjoining hollows and twice as much above the stream valleys. Nearly all the area is under cultivation, excepting occasionally a very bouldery knoll or hillside; and many of the farmhouses are quite picturesquely ensconced among the moraine hillocks or in partly wooded ravines. In a walk of some eight or ten miles upon this tract, I found its material almost wholly till, everywhere having plentiful boulders, with very scanty kame gravel and sand, or none; but in many parts of the belt southward, it consists largely of kame deposits, usually in smooth massive hills similar to those of the principal terminal moraine on Long Island in its course east from Roslyn. Between Frederikshavn and the Limfjord the width of this compound moraine belt is fifteen to twenty miles.

Continuing southward, this belt, diversified by frequent small lakes, occupies in general the eastern third or half of Denmark. It attains its greatest altitude in the broadly rounded hill named Ejer Bavnehöj, 564 feet above the sea, seen within two miles west of our railway and probably 200 feet above it, a few miles southwest of Skanderborg. Drift covers nearly all the peninsula so deeply as to give no outcrops of the underlying formations; and west of the morainic till it is described as mostly stratified gravel and sand, in undulating swells and in plains sloping away from the moraine belt.

Through Schleswig our railway, passing south from Lun-

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derskov by Woyens, to Flensburg, Schleswig and Rendsburg, traverses a slightly undulating plain of modified drift, mainly varying in altitude from 100 to 250 feet above the sea, but declining southward to only twenty-five feet, or in part less, beside the river Eider and the Kiel ship canal at Rendsburg. The west border of the morainic hills lies from three to five miles east of the railway along this distance of about eighty miles; and they rise prominently above the plain in a well defined and continuous series from Flensburg southward, their tops being 200 to 350 feet above the sea.

In Holstein the principal line of morainic accumulation curves southeast, east and northeast, past Neumünster and Eutin, forming an interlobate series of hills, some of which rise 400 to 500 feet above the sea within a dozen miles north and northeast of Eutin. Thence turning back to the southwest, south and southeast, past Segeberg, this principal moraine occupies a width of about six miles where it is intersected by the Hamburg-Lübeck railway, from one mile southwest to five miles northeast of Oldesloe. Here it has a typical contour of irregularly grouped hills and ridges, 50 to 100 feet above the intervening depressions; and its material is mostly gravel and sand, boulders being rare on its southwestern part but frequent northeastward.

Passing through Lauenburg and Mecklenburg, this great moraine, in width and hight similar to prominent portions of the moraines of the United States, resembles them too in the loops of its course, convex southward, with especially massive accumulations on its interlobate tracts. It sweeps from Oldesloe southeast, east and northeast, past Mölln, Boddin and Crivitz; is crossed by the railway between five and ten miles west of Bützow, and thence extends re-entrantly north past Kröpelin to the Baltic shore ten to fifteen miles west of Warnemünde. Returning toward the southeast, it is again intersected by the railway between one and six miles north of Schwaan, whence it continues southeast to the moraines which have been mapped west and east of the Oder. Such grand loops also characterize this belt in its farther extent past Neustettin, Dantzic, Ortelsburg and Lyck, to the international boundary.

Having held a conspicuous development across northern

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Germany, the Baltic ridge will quite surely be found traceable far onward in Russia. If we follow the outline of the country bearing frequent or abundant lakes, so generally coextensive with the late glacial drift and its moraines, whether in North America or Europe, we pass from Prussia northeast to the Valdai hills, which are the most prominent elevations in central or western Russia, although at their highest points only about 1,100 feet above the sea. These hills are described by Nikitin as composed of morainic drift. The border of the lake-dotted country leads us still forward northeasterly to the Arctic ocean near the middle of its Russian coast, somewhat east of the White sea. I can not doubt that distinct lines of marginal drift will be traced, when carefully looked for, along this distance of about 1,300 miles, completing an outline of the border of the European ice-sheet when its rapid final melting, attended with the formation of great marginal moraines, began.

Along all its course, from the British Isles, across the North sea, through Denmark, Germany, and Russia, this boundary of the moraine-bearing drift, as in North America, lies at a considerable distance back from the drift limits of earlier glaciation. It testifies that the conditions under which the marginal drift ridges and hills originated, during stages in the general retreat of the continental ice-sheet, were dependent on the great climatic change brought about by the depression of the ice-covered parts of both continents in the Champlain epoch. Then the borders of the ice-sheets, on account of their marginal melting, presented steeper slopes than before; much of their englacial drift became superglacial; and the deposition of the drift at the ice-front, both beneath and upon the margin of the waning ice-fields, was promoted by vigorous glacial currents, which, however, were surpassed by the rapidity of the summer melting. The moraines, in their parallel succession, were amassed with only short intervals of time separating them, as compared with the prolonged earlier stages of the Glacial period.*

*The general conditions of accumulation of marginal moraines are discussed in my former papers in the Am. Geologist, XVI, 107-113, August, 1895, and XIX, 411-417, June, 1897. For the Baltic ridge, German geological opinions of the time and manner of its formation have been well given by Dr. Wahnschaffe in his work reviewed by Prof. Salisbury in the Am. Geologist, IX, 294-319, May, 1892.

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In my correlation of the Baltic ridge westward with the British moraines of Lewis and eastward with the Valdai hills and the limits of plentiful lakes in northern Russia, I differ from the mapping of DeGeer and Geikie. Instead of the southwestern boundary given for the "Baltic glacier" in the new edition (1894) of Geikie's "Great Ice Age," another marginal moraine, which should probably be correlated with De Geer's Swedish boundaries of the Baltic stage in the glacial recession, extends, as I observed it, across the island of Seeland (Zealand), passing northwestward from the ice-crushed hills of Rügen and Möen to Hammer and Næstved, thence northerly to the peninsula between the Ise fjord and Roskilde fjord, and thence northeastward to Helsingör (Elsinore), where it connects with the line traced by DeGeer across Scania, the southern extremity of Sweden. With this boundary we may, following DeGeer, correlate the more northern moraine which crosses the Wetter and Wener, and his moraine on the island of Oesel, and the moraines of Finland; but these belong, according to the conclusions of this paper, to a later recessional stage than the moraines of the Danish peninsula and of Mecklenburg and Prussia, which are well named by glacialists as the Baltic ridge.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Geology of the Yukon Gold District, Alaska. By JOSIAH EDWARD SPURR. *With an Introductory Chapter on the History and Condition of the District to 1897*, By HAROLD BEACH GOODRICH. (From the Eighteenth Annual Report, U. S. Geol. Survey, Part III, pp. 87-392, with plates 32-51, and figures 7-25 in the text. Washington, 1898.)

The field work on which this report is based was done in the summer of 1896 by the author, with H. B. Goodrich and C. F. Schrader as assistants. The oldest rock formation in the gold region is granite, usually more or less schistose or gneissic, and sometimes passing into mica schist. Next in ascending order is the Birch Creek series, roughly estimated as possibly 25,000 feet thick, consisting mainly of quartzitic rocks, generally thin bedded or schistose, with abundant quartz veins, which carry gold with pyrites and sometimes galena.

Above the Birch Creek series, and in general closely associated with

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it, is another thick series of rocks, named the Fortymile series because of its development on the creek of this name. The latter series includes alternating beds of marble, from a few inches to fifty feet thick, and quartzitic and other schists, with dikes of eruptive granites and diorites, and with many quartz veins.

These two rock series, which are regarded as the principal sources of gold in the placers, are known to be older than the Carboniferous and Devonian formations of the Cordilleran mountain system, and are thought to be pre-Cambrian. The numerous younger rock series of the region, and the placer gravels which are the chief object of interest to prospectors in the present stage of development of the gold mining, are also very fully described.

The report relates chiefly to the Alaskan possessions of the United States, but comprises also incidental notes of the Klondike district on the British upper part of the Yukon. It is accompanied with many maps and sections, and will be of great service to prospectors. For their convenient use, also, an abstract of the two Alaskan reports here noticed has been prepared, as a separate and abridged publication of the U. S. Geological Survey, by Dr. S. F. Emmons, in 44 pages, with a large map of Alaska and descriptions of the routes to the gold fields.

W. U.

Studies on Cambrian Faunas. By G. F. MATTHEW. (Trans. Royal Soc. Canada, 2nd ser., vol. 3, sec. 4, pp. 175-211, pls. 1-4, 1887.)

This essay is divided into two parts; the first treats of a new subfauna of the *Paradoxides* beds of the St. John group, the second describes certain of Billings' Primordial fossils of Vermont and Labrador. The fauna described in the first part of the paper is claimed to be equivalent to that of the upper *Paradoxides* beds of Sweden. Among the fossils is a genus not heretofore recognized in America, viz. Angelin's genus *Dolichometopus*. Several species of *Dorypyge* occur in this fauna, also species of *Anomocare*. The prevailing species of Agnosti are Longifrontes, Brevifrontes and Lævigati. Several new species of *Agraulos*, one of *Liostracus*, one of *Conocoryphe*, one of *Ptychoparia* and one of *Dorypyge* are described. Many species of the fauna have representative forms in Bohemia, Great Britain, etc.

The author claims that he has established a close relationship between this fauna and that of *Olenellus* through the genus *Dorypyge* and other types, and suggests that here may be the proper stratigraphical place for it, rather than below the *Paradoxides* beds.

The second part of the article is taken up with a description of such species of Billings' Primordial fossils of Vermont and Labrador as were studied in connection with the Cambrian fauna above described. The investigation induces Dr. Matthew to think that Billings' species should be classed as Middle rather than as Lower Cambrian. This opinion appears to be based on the presence of the genera *Bathyuriscus* (allied to *Dolichometopus*), *Dorypyge* and *Anomocare*.

Four plates of figures are given of the new species and varieties of the new subfauna, and of the species of Billings' Primordial fauna fossils that are discussed in this paper.

G. F. M.

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Palæontologische und stratigraphische Notizen aus Anatolien. I. Der Lias am Kessik-tash W. von Angora, etc. Von J. F. POMPECKJ, in München.*

This article describes the several zones of the Lias recognized near Angora in Anatolia. The first part is a description of the fossils found. Foraminifera of the groups *Texularidæ* and *Rotalidæ* were met with; also *Heliodiscus* among the radiolarians. Crinoids of the genus *Pentacrinus* (*Extracrinus*) form a part of the collection. A *Terebratula* was obtained, also a *Pleurotomaria* (*P.* cf. *amathei* Quenst.). *Cephalopoda* form an important part of the fossils gathered. The species are *Phylloceras frondosum* Raynes, *P. herbertinum* Raynes, *P. alontinum* Gemmellaro, *Lytoceras* sp. ex. aff., *L. ampli* Opp., *Arietites* cf. *rotator* Raynes, *A.* cf. *latisulcatus* Quenst., *Belemnites* sp. indeterm.

A study of these species leads Dr. Pompeckj to assert the presence of the Lower, Middle and Upper Lias at Kessik-tash, and comparisons are made with the Lias of the Mediterranean and northwest areas in Europe.

An interesting part of the article is a discussion of the relations of land and sea in eastern Europe and western Asia in the Liassic age. Dr. Pompeckj postulates the existence of an island whose area covered the Archipelago, eastern Greece and Thrace and the Balkan region in the time of the Lias. This island was separated from a northern mainland by a narrow strait in eastern Hungary. The northern land is called the South-Russian mainland and the sounthern boundary includes the mouths of the Danube, the Crimea and the plains north of the Caucasus; from this range the boundary swept around to the south and included the valley of the Caspian sea. Asia Minor and Persia thus formed a marine region, but there was a free connection between it and the Mediterranean area, as there was no independent fauna in the eastern sea.

The existence of a northern mainland is further strengthened by the presence of a Rhætic flora in the Alburz mountains of northern Persia which, according to Dr. Pompeckj, is here the northern boundary of the Liassic sea.

The article is furnished with a map showing the geographical features above indicated, and with three plates bearing figures of the species found at Kessik-tash. G. F. M.

History of Mining and Quarrying in Minnesota. By WARREN UPHAM. (Minnesota Historical Society Collections, vol. 8, pt. 2, pp.291-302, May 10, 1898.)

The substance of this paper was delivered as an address at the annual meeting of the Minnesota Historical Society, Jan. 18, 1897. The paper deals with the various substances which have been or which are mined or quarried in the state and gives a brief account of the development of the industry connected with each. The subjects treated are: copper, gold, iron, coal, granite and gneiss, quartzyte and sandstone, limestone, clay. Some statistics are presented and there is also a popular resumé of the geological history of Minnesota. U. S. G.

*From Deutchen Geologischen Zeitscrift 1897. Pt. 4 pp. 713-828. 2 cuts, 1 map, 2 plates.

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The Valley Regions of Alabama (*Paleozoic Strata*). By HENRY MCCALLEY, Assistant State Geologist.—Part I. The Tennessee Valley Region. Pages 436, with Plates I-IX, and four figures in the text; 1896.—Part II. The Coosa Valley Region. Pages 862, with Plates X-XXXV, and figures 5-18 in the text; 1897.

These are reports of the Geological Survey of Alabama, which has been doing excellent work, under the direction of Dr. E. A. Smith, during twenty-five years. They describe the northern two-fifths of the state, in which its chief mineral resources are found, including the rich deposits of iron ores and coal which have been extensively worked in the Birmingham district. The strata of the Coosa region, folded, faulted, and eroded, form the southwestern end of the great Appalachian mountain belt, with much picturesque scenery. Northward the geological structure changes until the rocks are nearly level in stratification; but they have been eroded by the streams to form great plateaus, some of which rise 1,200 feet above the valleys, or 2,000 feet above the sea, being the highest land in the state. After general descriptions of the two regions, each is treated in much detail in chapters describing the several counties. The formations range in age from the Cambrian to the Carboniferous, and are illustrated by twenty-eight sections which cross the Coosa region from southeast to northwest, nine of these sections being continued across the Tennessee river. W. U.

Summary Report of the Geological Survey Department [*of Canada*] *for the year 1897*. 156 pages; Ottawa, 1898. Price 10 cents.

Fifteen field parties were employed by this survey last year, two being in British Columbia, two in the Northwest Territories (engaged in experimental borings for petroleum and natural gas in the Athabasca and Saskatchewan region), four in Ontario, one in the province of Quebec, one in New Brunswick, three in Nova Scotia, and two on the shores of Hudson strait. Extensive deposits of corundum, which will probably be of economic importance, have been found, as here described and mapped, in Hastings and Renfrew counties, Ontario. The West Kootenay mining district and other gold-bearing areas north of the Lake of the Woods and of Rainy lake and in Quebec, New Brunswick, and especially Nova Scotia, have been examined and are somewhat fully noted, for the guidance of prospectors.

Along the St. Lawrence valley the Late Glacial lacustrine and marine shore lines have been traced by Mr. Robert Chalmers, who also has further investigated the glaciation of that region. He concludes that earliest a northwardly flowing ice-sheet extended from the mountainous southern watershed to the St. Lawrence; that later the very thick Laurentide ice-sheet, moving southward, overflowed the whole valley (and it may be added that it carried boulders, as shown by Prof. C. H. Hitchcock, to the top of Mt. Washington and across the Green mountain range); that this was succeeded by local glaciers flowing down from the highlands on each side of the St. Lawrence valley; and that lastly floating ice produced a general southwestward striation in the valley during its Champlain marine submergence. It is admitted,

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however, that these valley striæ running southwest may be attributable to deflection of that part of the Laurentide ice-sheet at its time of final melting, which interpretation seems to the reviewer more probable. According to this view, the western front of the ice-sheet that covered the St. Lawrence valley, holding a glacial lake on its southwest side, retreated northeasterly along a great extent of the valley and remained latest in the vicinity of Quebec or farther east, finally disappearing from the valley while yet large tracts of ice enveloped the higher country on the south and north. W. U.

Das Palæozoicum Polnischen Mittelgebirge. By DR. GEORGE GURICH. (Trans. Imperial Mineralogical Society of Russia, vol. XXX, 1896.)

The district described in this memoir is in southern Poland, mainly in the country between and around Kielce and Opatów. This region has been subjected to considerable oscillation, and the rocks are folded and faulted to a marked degree. The geological section extends from the Cambrian to the top of the Devonian, and the strata reach their greatest development in the Devonian. The Cambrian is represented by a single member, the Silurian by four members, and the Devonian by twenty. The Devonian fauna is especially rich, and represents, together with others, the typical zones of *Rhynchonella caboides*, *Stringocephalus burtini*, and *Goniatites intumescens*, so characteristic of certain faunas and horizons in other parts of the world.

The new genera described comprise *Plagiopora*, a tabulate coral; *Ceratophyllum* and *Hexagonum* cyathophylloid corals; *Spirillopora*, a bryozoan; and four genera of ostracods, *Antitomis*, *Trigonocaris*, *Polyzygaria*, and *Poliniella*.

Interesting studies are made on the amount of crustal oscillation, and the nature of the sediments, whether shore, near shore, off shore, or deep sea. These observations are plotted in curves, on tables of the geological succession for various localities. C. E. B.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Agassiz, Alexander.

A visit to the Great Barrier reef of Australia in the steamer "Croydon," during April and May, 1896. (Bull. Mus. Comp. Zool., vol. 28,—Geol. ser. vol. 3,—no. 4, pp. 95-148, 42 pls., Apr. 1898.)

*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

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Bain, H. F.

The Bethany limestone at Bethany, Missouri. (Am. Jour. Sci., ser. 4, vol. 5, pp. 433-439, June 1898.)

Ballou, W. H.

The serpentlike sea saurians. (Appletons' Pop. Sci. Monthly, vol. 53, pp. 209-225, June 1898.)

Blake, W. P.

Anthracite coal in Arizona. (Am. Geol., vol. 21, pp. 345-346, June 1898.)

Claypole, E. W.

Paleolith and neolith. (Am. Geol., vol. 21, pp. 333-344, June 1898.)

Dawson, G. M.

Summary report on the operations of the Geological Survey [of Canada] for the year 1897. (156 pp.; Ottawa, 1898.)

Dawson, J. W.

Addendum to note on Nova Scotia Carboniferous Entomostraca in number for January, 1897. (Canadian Rec. Sci., vol. 7, p. 396, July 1897; issued Jan. 7, 1898.)

Dellenbaugh, F. S.

The causes of natural arches. (Science, new ser., vol. 7, p. 714. May 20, 1898.)

Earle, Charles.

Relationship of the Chriacidæ to the primates. (Am. Nat., vol. 32, pp. 261-262, Apr. 1898.)

Evans, John.

Presidential address before the British A. A. S. (Canadian Rec. Sci., vol. 7, pp. 399-426, July 1897; issued Jan. 7, 1898.)

Grabau, A. W.

Geology and palæontology of Eighteen Mile creek and the lake shore sections of Erie county, New York. (Buffalo Soc. Nat. Sci., Bull., vol. 6, no. 1, xxiv and 91 pp., 27 pls., 1898.)

Gresley, W. S.

Some new Carboniferous plants, and how they contributed to the formation of coal-seams. [Abstract.] (Quart. Jour. Geol. Soc., vol. 54, pt. 2, p. 196, May 2, 1898.)

Gresley, W. S.

Cone-in-cone: additional facts from various countries. [Abstract.] (Quart. Jour. Geol. Soc., vol. 54, pt. 2, p. 196, May 2, 1898.)

Hill, R. T.

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CORRESPONDENCE.

RECENT SEVERE SEISMIC DISTURBANCES IN NICARAGUA. A series of earthquakes commenced in western Nicaragua about 10:40 A. M. on April 29th, 1898, being felt as slight tremors on the eastern side of lake Nicaragua and increasing in their rapidity of motion and strength of force developed as the line of greatest disturbance extended,—nearly parallel with the volcanic belt,—northwardly to the Pacific ocean at the entrance to the gulf of Fonseca, and thence into Salvador. The undulations continued about twice each twenty-four hours until May 12th, 1898.

The first of the series was very much the strongest and most de-

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structive to houses of any occurring in Nicaragua during the past half century, developing an intensity estimated by the Rossi-Forel scale of iv to ix, along its course from the west side of lake Managua to the Pacific ocean, a distance on the line of its movement of about 140 miles. It passed through Managua, the capital of Nicaragua, at the rate of about 600 millimetres per second, through Leon at about 800 mm. per second, and through the towns of Chinandega and El Viejo at a rapidity of wave movement or progression of about 900 mm. per second.

The tile-roof covering of many houses in Managua, Leon, Chinandega and El Viejo was displaced and part of the roof thrown to the ground, and the walls of hundreds of thick-walled, one-story, adobe houses were severely fissured, many beyond repair. Also the five-feet-thick, carefully constructed, cement and brick walls of the cathedral in Leon were cracked.

Several of the volcanic formed masses and cones along the line of the greatest expression of the force of the first series, west of lake Managua, were sufficiently disturbed to cause some greater activity than usual in the hot mud springs near their ridges or apices and in the boiling springs at their bases, but there has not been exit of force enough at once through any volcano in the belt of seismic disturbance to cause active volcanic eruptions.

There was no jarring motion felt, as is invariably felt when large areas of strata fall from the inner roof,—through gases and aqueous vapors at high tension and highly heated magma,—toward the floor of some sub-volcanic cavern or cavernous locality. Neither were any of the lateral movements felt,—those at an angle to the general direction of the movement of the force,—that are invariably distinct and frequent when the origin of the force is from a disturbed condition of heated materials, gases and aqueous vapors at extreme tension beneath volcanic masses, as they force and fissure their way up to the earth's surface.

The evident origin of the development of force in this series of earthquakes appears to have been from a contracting of the earth from loss of heat and a consequent sliding of the strata into more compact conditions. The waves as they developed at the earth's surface were comparatively short and high and more regular than is usual in earthquakes from other causes. The apex of one wave arose at the earth's surface beneath one wing of the large one-story building occupied by the bank in Managua and, parting the tile roof, caused the forward part of the roof to slide from its former position a distance of about ten feet northwardly,—along the direction that the waves of force were moving. The other part of the roof moved southwardly about eight feet.

The first of this series of earth disturbances was preceded for a few seconds by a very rough grating sound, followed by a few seconds of tremors and slight undulations, and then severe movements undulated for about thirty seconds.

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The writer has none but improvised seismic instruments, improved on as used for several years, and but few of them were in good working condition when the first severe seismic disturbance in this series passed. The direction of the waves was northwardly and southwardly, and the rapidity of their movement was about as herein stated.

Managua, Nicaragua, May 19th, 1898. J. CRAWFORD.

THE ST. CROIX RIVER VALLEY. In the descriptions of the St. Croix river valley brief references have been made to the preglacial and postglacial courses of the river. The definite relation of these courses has not been determined. Mr. Warren Upham states, that the occurrence of the Upper and Lower Dalles of the St. Croix strongly suggests that there, and along some contiguous extent of the present valley, the stream is now flowing in a course which it has cut during and since the Ice age. No closely adjacent belt, however, seems to be probably identifiable as a drift filled preglacial valley. In preglacial times the St. Croix river was represented by two quite independent rivers, each tributary to the Mississippi. The greater part of the St. Croix drainage basin including all above Taylor's Falls flowed south and southwestward from the mouth of the Sunrise river to a junction with the Mississippi somewhere between Anoka and Minneapolis. * * * * About a sixth part of the St. Croix basin lying east and south of Taylor's Falls appears to have been drained by a stream coinciding nearly with the Apple river and the lower thirty miles of the St. Croix river.*

The recent observations of Dr. C. P. Berkey, in the vicinity of the Dalles, also indicate the postglacial character of that part of the gorge.†

The St. Croix valley varies from one-half to one mile in width and is 168 miles long. Based upon the various physiographic features, the valley presents three sharply defined parts designated in this paper the Upper, Middle and Lower St. Croix.

The Upper St. Croix. Beginning at the Upper St. Croix lake the course of the St. Croix valley extends in a southwesterly direction for 90 miles, to the northeast corner of Chisago county in Minnesota. Thence it extends nearly south for ten miles to the Big bend at the mouth of the Sunrise river. In this distance of 100 miles the river descends 310 feet. The valley has an average depth of about 100 feet. From the abundant undisturbed glacial drift below the top of the early rock gorge it is evident that the valley is essentially of preglacial origin. During postglacial time the river has cut through the drift in many places and is now cutting its way below the preglacial surface. The tributaries to the Upper St. Croix show the same relations between the preglacial and postglacial erosion. In the vicinity of Sandstone, Minnesota, the Kettle river flows in a preglacial gorge from 100 to 150

*The St. Croix river before, during, and after the Ice age, p. 48, by Warren Upham. Report of the Commissioner of the State Park of the Dalles, 1896. pp. 45-58.

†Geology of the St. Croix Dalles, p. 367. Amer. Geol., vol. XX, Dec. 1897.

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feet deep. The postglacial rock erosion is however small compared with that during preglacial time.

The Middle St. Croix. Special attention is called to this part of the valley because it seems that here the river was compelled to abandon its preglacial course and to form the present gorge which again unites with the preglacial valley in the Lower St. Croix. The present course of the Middle St. Croix is 27 miles long and for reasons appearing below is divided into three sections.

Amador Section. At the Big bend the St. Croix valley makes an abrupt turn and extends east for four miles and then southeast for ten miles to the mouth of Rock creek. This part of the gorge is designated the Amador section because it forms the northeast boundary of Amador township in Chisago county. The Amador section follows the course of a small preglacial stream which flowed northwestward. Glacial erosion widened and deepened the preglacial valley The main erosion features however indicate that the gorge is chiefly of postglacial erosion.

The Dalles Section. From Rock creek the St. Croix gorge extends south three miles to the Upper Dalles, and then southwest three miles to the Lower Dalles and Franconia. The descriptions of this section by Mr. Upham and Dr. Berkey show that the gorge here is essentially of postglacial origin.

The Osceola Section. From Franconia the gorge extends south three miles to Osceola, Wis., and then southwest four miles to a point about one mile north of the bridge of the Minneapolis, Sault Ste. Marie and Atlantic railway. At this point, locally known as Prairie hollow, the river makes an abrupt bend to the east of south and the valley suddenly becomes much wider. The several drift sheets appear in place above the rock strata on both sides of the gorge and have every appearance of having been continuous at one time. The bottom and sides of the gorge show no signs of glaciation. The drift found below the top of the rock strata has fallen down from the layers of till above. The present gorge, in part follows and cuts across narrow and shallow drift filled gorges whose preglacial streams flowed westward.

The Middle St. Croix river in its distance of 27 miles falls 78 feet. The valley bears a strong contrast to that of the Upper and Lower St. Croix, in the absence of undisturbed glacial drift, in its clear cut features and in its youthful appearance.

The Lower St. Croix. From Prairie hollow the St. Croix valley extends in a southerly direction for 41 miles, to its junction with the Mississippi valley at Prescott, Wisconsin. The Lower St. Croix valley is entirely due to preglacial erosion. The river has nowhere succeeded in cutting entirely through the glacial drift. The Lower St. Croix river falls only 13 feet.

The buried gorge. In tracing the course of the St. Croix river on a good map of this region, it is noticeable that if the Middle St.

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Croix had continued in the direction of the lower part of the Upper St. Croix its course would be from the Big bend through Sunrise City, Center City and Chisago lake to Prairie hollow where it would join the Lower St. Croix without making an abrupt bend as is now the case. This distance is 20 miles, —seven miles shorter than its present course. The region between the Big bend and Prairie hollow is covered with drift averaging over 100 feet in thickness and having a rough morainic contour over the greater part of the distance, but the following facts seem to warrant the conclusion, that in preglacial time the Middle St. Croix followed the course indicated above, from the Big bend to Prairie hollow.

A depression about a mile wide and from fifty to one hundred feet deep extends, as a continuation of the Upper St. Croix valley, about four miles south of the Big bend. The bed of the Sunrise river in the last two miles of its course is below the rock formations on either side of the valley. The wells in the vicinity of Sunrise City extend about 50 feet below the bed of the Sunrise river and in no case have they reached rock bottom.

At Prairie hollow the rock walls of the gorge of the Lower St. Croix continue northward one-fourth of a mile beyond the end of the Middle St. Croix gorge. The extension of the gorge is filled with drift and near its west side is a drift hill about 300 feet above the river. Prairie hollow is the sandy prairie formed at the base of this hill. Between the high drift hill and the eastern side of the gorge is a depression which extends northward until it is lost in the morainic contours of the drift, over three miles from the river. This valley is about a mile wide and from 50 to 200 feet below the drift hills on either side. For some distance the valley is below the top of the rock formations in this vicinity. Well borings show that a buried preglacial gorge extends at least three miles north of Prairie hollow. Beyond this wells do not extend deep enough to be of assistance. Copious springs are abundant at Prairie hollow and issue from the lower layers of the drift which fills the preglacial gorge. The water from these springs forms two large creeks which empty into the St. Croix. In the present gorge below and above Prairie hollow springs are relatively very scarce.

The only evidence of the buried gorge in the intervening territory is that afforded indirectly by Chisago lake. This large lake has no surface outlet. The lake rises and falls independently of the quantity of rainfall, of the season and the condition of the surrounding region. The subterranean outlet seems to be permanently located, for whenever the lake falls rapidly the water from all parts of the lake always flows toward the same point. It is probable that the springs at Prairie hollow are the outlet of the underground stream which discharges the water of Chisago lake and whose course is determined by the buried preglacial gorge.

The Middle St. Croix lies in the region occupied at various times, separately and together, by the glaciers extending from the Keewatin

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and Laurentide ice sheets. At the close of the Kansan stage the St. Croix probably still followed its preglacial course. The Iowan drift sheet effectually blocked this course. The interglacial stage between the Iowan and Wisconsin drift was very short in this region and it appears that the present Middle St. Croix valley is chiefly of postglacial origin. The Middle St. Croix valley affords an additional case for the computation of postglacial time. The problem is highly complicated by the number and the great variance of the factors which must be considered. Each section of the Middle St. Croix presents a group of factors quite different from that of the other sections. It is evident that the time interval represented by the erosion of the present Middle St. Croix is very long. The writer is of the opinion that 40,000 years will represent approximately the duration of postglacial time as expressed by the history of the St. Croix valley.

The above preliminary note is intended to announce the determination of the definite relationship of the preglacial and postglacial courses of the St. Croix river. A detailed description and discussion of the problems involved will follow at a later date.

Minneapolis, April 23, 1898. A. H. ELFTMAN.

PERSONAL AND SCIENTIFIC NEWS.

PROF. R. S. TARR is spending the summer in the Rocky Mountain region and the Pacific States, traveling extensively to visit localities of special geological interest, in behalf of his department in Cornell University.

CORNELL UNIVERSITY. An instructorship in economic geology has been created in the geological department of Cornell University, and Dr. Heinrich Ries of Columbia University has been appointed to the position.

GEOLOGICAL SOCIETY OF WASHINGTON. At the meeting of May 25th the following papers were presented:

Pitch Coal from Oregon. J. S. Diller.

Distribution and quantitative occurrence of vanadium in rocks of the United States. W. F. Hillebrand.

The Devonian in southwestern Colorado. A. C. Spencer and G. H. Girty.

A geological excursion in southern Russia. S. F. Emmons.

NEW YORK ACADEMY OF SCIENCES. Section of Geology and Mineralogy, May 16, 1898.—Mr. Geo. F. Kunz exhibited specimens of quartz crystals found in massive gypsum at Gallineo Springs, N. Mex., and announced the discovery of a new meteorite from Ottawa, Kas.

The first paper on the programme was by Prof. D. S. Martin on "The Geology of Columbia, S. Ca., and its Vicinity."

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Prof. Martin described the granite and gneissic rocks of that region and their residual products. He also commented on the character of the Potomac, Lafayette and Columbian formations which are well exposed in the railroad cuts south of the city. The paper was discussed by Prof. Dodge and Dr. Ries.

The next paper of the evening was by Prof. J. F. Kemp on "Some Remarks on Titaniferous Magnetites." The speaker discussed the formula of ilmenite and stated that it was probably a mixture of $FeO{\cdot}TiO_2$ and $n\ Fe_2O_3$. The amount of titanium present in the titaniferous magnetites is very variable, running sometimes as high as 40 per cent; in the Adirondack ores it is 10 to 20 per cent. Magnetic methods of separation have not yet proved successful for the elimination of the titanium. Nearly all of the titaniferous magnetites show small amounts of MnO, Cr_2O_3, CoO, NiO, V_2O_3 and MgO. The latter suggests the presence of spinel. SiO_2 and Al_2O_3 have also been found, but phosphorus and sulphur are rare. Prof. Kemp suggested that these rarer constituents might have some influence on the metallurgical behavior of the ore. The native and foreign occurrences of the ores were alluded to. Discussion of the paper was by Prof. Martin, Dr. Ries and Mr. Kunz.

HEINRICH RIES, *Secretary.*

GEOLOGICAL SOCIETY OF AMERICA. The tenth summer meeting of this society will be held, in conjunction with the American Society for the Advancement of Science, Tuesday, August 23rd, in the lecture hall of the Boston Society of Natural History, Boston, Mass. The council will meet Monday evening, August 22nd, and the society will be called to order on Tuesday morning at 10:30 o'clock. The hotel headquarters is the Copley Square. The preliminary announcement circular of the A. A. A. S., which convenes August 22nd, will be sent to the fellows of the Geological Society who are not members of the Association. All arrangements described in this circular relating to entertainment, transportation, etc., apply to the Geological Society and other societies meeting in conjunction with the Association.

PROF. EDWARD W. CLAYPOLE, of Buchtel College, Akron, Ohio, has accepted the chair of science in the Polytechnic Institute of Pasadena, California. He expects to enter upon his new duties in September.

PROF. N. H. WINCHELL, managing editor of this journal, has been spending the past few months in Paris in petrographical study and investigation. He expects to return home the latter part of June.

THE GEOLOGICAL DEPARTMENT OF THE JOHNS HOPKINS UNIVERSITY has just closed an encampment of sev-

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eral weeks near Cumberland, Maryland, in the heart of the Appalachian mountains. Work was suspended in Baltimore during the period of the camp, special courses being given at Cumberland, both by the regular corps of instructors and by lecturers secured from the scientific bureaus in Washington. Complete instrumental outfits employed in geological, topographical, climatological, hydrographical and agricultural investigations were installed at the camp, special lectures being given upon their uses. In addition to practical work along geological and topographical lines, meteorological observations were taken twice daily by the students, under the direction of an observer detailed by the United States Weather Bureau, the streams were gauged and the velocity and volume of their outflow determined, and the conditions of the soils in their temperature and moisture contents were examined daily under competent supervision. Among those who were present at the camp and who aided Prof. Clark and his associates in the work of instruction were Messrs. Bailey Willis, H. M. Wilson, O. L. Fassig, E. G. Paul, and C. W. Dorsey, of the Washington bureaus. It is planned to continue practical field work in this manner in subsequent years. (*Science.*)

THE INTERNATIONAL MINING CONGRESS will assemble in Salt Lake City, Utah, at 10 a. m., Wednesday, July 6th, and continue at the pleasure of the Congress during the 7th, 8th and 9th. The Congress is a permanent organization, and is a direct outcome of the International Gold Mining Convention which was held in Denver last July. In the official call issued for the Denver meeting the following explanation of the objects of the Congress were given. "The objects of the Convention are to secure such national legislation as may be calculated to promote the business interests and development of the resources of the mining industry in North and South America; to bring together mining men and investors; to increase reciprocal trade among them; to discuss such questions as are naturally suggested by its objects; to cultivate acquaintance, fraternal feeling and hearty co-operation among various mining, commercial and labor bodies represented; and especially to take under advisement the importance of the creation, by Congress, of a department to be known as the Department of Mines and Mining, thus securing a cabinet officer that represents an interest which affects more than one-third of the people of the United States."

IMPORTANT VERTEBRATE FOSSILS FOR THE NATIONAL MUSEUM. Prof. O. C. Marsh has recently transmitted from New Haven to the director of the United States Geological Survey the fourth large installment of vertebrate fossils secured in the west, in 1882-92, under his direction as paleontol-

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ogist of the United States Geological Survey in charge of vertebrate paleontology. The collection is packed in one hundred boxes, and weighs over thirteen tons. In accordance with law the material will be deposited in the National Museum. This collection includes twelve skulls and other remains of the gigantic *Ceratopsia* from the Cretaceous; various *Dinocerata* fossils from the Eocene; a series of rare specimens of *Brontotherium*, *Elotherium*, *Miohippus*, and other genera, from the Miocene; a very extensive collection of *Rhinoceros* and other mammals from the Pliocene; as well as various interesting fossils from more recent deposits.

The other important collections of vertebrate fossils secured by Prof. Marsh in the west for the Geological Survey, and previously transferred to the National Museum, may be briefly enumerated as follows: (1) Seventy-two large boxes of Pliocene fossils, weighing 7,500 pounds, were transferred Dec. 31, 1886, and were stored in the Armory, Feb. 8, 1887. The record of these boxes is on file in the office of the Geological Survey, and the Smithsonian numbers of the boxes are 6601-6672. (2) Thirty-three large boxes (weighing 6,960 pounds) of rare vertebrate fossils, ready for exhibition, were transferred July 17, 1891, and were placed in a case specially prepared for them in the National Museum, before the opening of the International Congress of Geologists held in Washington that year. (3) Forty-three large boxes (weighing 4,380 pounds) of Pliocene vertebrate fossils were transferred April 17, 1896.

These various collections with other smaller consignments transferred to the National Museum (255 boxes in all, with a total weight of over twenty tons) were secured under the special direction of Prof. Marsh, as paleontologist of the U. S. Geological Survey in charge of vertebrate paleontology, during 1882-92. The remaining collections thus made, and still at New Haven, will be sent to Washington as soon as their scientific investigation now in progress is completed.

KARL LUDWIG FRIDOLIN VON SANDBERGER, until recently professor of mineralogy and geology in the University of Wurzburg and director of the Mineralogical Institute in that city, died on April 11th. Prof. Sandberger is noted for his investigations in mineralogy, in ore deposits, in petrology and in fossil mollusca. His important work on mineral veins, —"Untersuchungen über Erzgänge"–was published in 1882-85. During the last years of his life he was devoted more particularly to mineralogy. In 1855 he was granted the Wollaston fund by the Geological Society of London, and in 1875 he was elected a foreign member of that society.

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REMAINS OF A SPECIES OF BOS IN THE QUATERNARY OF ARIZONA.

By WILLIAM P. BLAKE, Tucson, Arizona, and Mill Rock, New Haven, Ct.

The plains and valleys of Arizona in ancient Quaternary time were the feeding ground of a species of Bos, now extinct. This is shown by the discovery of fossil horn-cores of gigantic size, and well preserved in the ancient cemented gold-bearing gravels at Greaterville on the eastern side of the Santa Rita mountains in Pima county, about thirty miles southeast of the city of Tucson. They were exhumed by the sharp pick of one of the placer miners, Mr. P. J. Coyne, to whom and to Mr. Thos. Deering, of Greaterville, we are indebted for the preservation of the fragments and their presentation to the museum of the University of Arizona. From these fragments I was able to reconstruct nearly the whole of one core, and the greater part of the other. The outer portions of these bones are stained by oxide of iron, and portions of the cemented gravel and sand adhere in places to the surface.

These horn-cores are very much larger and heavier than any known to us amongst horned cattle, or Bos taurus of the present time. They are nearly twice as large as the horn-cores of largest size of our domestic bulls. It is evident that the animals must have had a very large skull and great strength of neck to support and make use of such ponderous horns.

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The dimensions of these fossils are as follows: Girth, or circumference, of the largest end at or near the base where it joined the frontal bone, 17⅜ inches=442 millimetres; the greatest diameter being 6 inches=152 milimetres in one direction, and 5½ inches=140 millimetres in the other; the section being somewhat elliptical. The length of the portion restored is 17 inches=432 millimetres. The tip of this horn-core is complete, but some fragments needed to make a connection with the larger part are missing, consequently the exact original length of the core cannot be stated, but it probably was 23 to 24 inches=650 millimetres long when complete. The circumference of the horn-core at a point 8½ inches from the base is 13⅝ inches=346 millimetres; and 13 inches=330 millimetres at 12 inches from the base.

The curvature is slight, and in one plane only. In this respect and in the form and proportion these horn-cores do not resemble the horn-cores of our American bison, B.americanus, nor do they resemble the horn-cores of the Asiatic bison, a skull of which is in the museum at Tucson. Compared with the familiar forms of horn-cores of our domestic cattle these fossil cores in all respects, except size, more nearly approximate the form and proportions of the horn-cores of the Hereford breed than any other. They are not like the short horns of the Durham or the long more slender and curved horns of the Holsteins. The form of the cores also suggests that they projected outwards, downwards and forward as in the Herefords rather than upwards and forwards.

While cognizant of the insufficiency of evidence presented by horn-cores alone for the foundation of a species it is certain that in these fossil bones of the ancient gold gravels we have evidence of the former existence at a remote period relatively to human occupation of an undescribed giant boviform animal for which for convenience of reference, at the least, I propose the name Bos arizonica.

Fossil horn-cores comparable in size with these of Arizona, but not certainly of the same species have been found in Texas, in Nebraska and other localities in the United States. So, also, in Europe where similar remains are more abundant, at least more have been found, and have been described as Bos primigenius.

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The occurrences in America have been noted chiefly by Carpenter, Harlan, Leidy and Marsh; while abroad we are indebted for description and memoir chiefly to Cuvier, Owen and Dawkins.

A brief resumé of this literature is desirable.

Cuvier as early as 1825* described several different specimens of the remains of Bos, and gave figures and measurements, cited later by Dawkins and others, and which will, also be found in the annexed tabular statement. Cuvier observes of the specimen, No. 1 of the table, that according to the proportion of Bos taurus the skull would indicate an animal twelve feet long and six and a half feet high at the withers. A more perfect specimen was dug from the peat bog of Saint Vrain in the Canton of Arpajon (No. 2 of the table). No. 5 of the table was taken from the drift of Clacton in Essex and was described by Mr. Brown, of Stanway,† and cited by Dawkins.

Dawkins in his memoir upon the "Fossil British Oxen," considers them under three heads or groups.‡ 1. The Great Urus, Bos urus of Julius Cæsar: 2. The small shorthorn, Bos longifrons of Prof. Owen: 3. The bison, Bos bison of Pliny. He states, "The large fossil ox of the Pleistocene period termed Bos primigenius by Bojanus and Prof. Owen differs in no respect from the Bos urus of the prehistoric and historical period." In Pleistocene times it wandered in vast herds over northern, central and western Europe, and according to Bojanus, over southern Russia and in company with the woolly rhinoceras (R. tichorinus), and the mammoth frequently fell a prey to the cave-hyena and the cave-lion. The date of its extinction in Britain is a vexed question. In Scania a skeleton was found in a peat bog. The animal had been hunted by man for it had been pierced by a javelin. Bones of this species are to be found in the lakes around the piles of the ancient lake dwellers. Its name occurs in the writings of Pliny, Martial and Seneca. Dawkins expresses the opin-

*Ossements Fossiles t. IV, p. 150, 3d Edition.

†Mag. Nat. Hist., n. s. 1838, p. 163.

‡W. Boyd Dawkins, M. A. F. G. S., "On the Fossil British Oxen," Quart Jour. Geol. Soc. Lon.. XXII, 392.

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ion that the larger cattle of western Europe at least are the descendants of Bos primigenius modified in many respects by restricted range but still more by the domination of man. Owen on the other hand thought that the tame ox of western Europe was probably derived from the already domesticated cattle of the Roman colonists. Baron Cuvier and Prof. Bell believed that the urus was, in part at least, the ancestor of our domestic breeds. It was the opinion of Prof. Nilsen that the large cattle of the Netherland and Holstein sprang from this animal.

In regard to Bos longifrons Owen wrote in 1847 that it co-existed with Megaceros in Ireland and with Megaceros, Rhinoceros, Elephas, Hyena, etc., in England. "Remains of this species have been found in ancient places of sepulture and so associated with British and Roman remains as to leave little doubt of its having survived as a species many of the mammals with which it was associated in the Pleistocene period."*

Dawkins, in his second paper,† combats this view of Owen that B. longifrons was a Pleistocene species and asserts that it had not yet been found to have existed before the prehistoric age; in the bone caves and alluvia of which it is found abundantly, and he also asserts that it is the ancestor of the small Highland and Welsh breeds.

The most important contribution to our knowledge of this subject was made by Dr. Jos. Leidy,‡ of Philadelphia, in his memoir on the extinct species of the American ox, published in volume V of the Smithsonian Contributions to Knowledge in the year 1852. In this memoir a review and resumé of the literature of the subject in the United States may be found. Dr. Leidy wrote that remains of extinct species of ox are quite abundant in the post-pliocene deposits of North America. He notes that such remains are numerous and are indigenous to all the continents excepting South America and Australia. The first distinct species of extinct American ox was announced to the world by Mr. Rembrandt Peale. This was based upon the specimen presented by Dr. Samuel Brown to the museum of the Philadelphia Academy of Natural

*Quart. Jour. Geol. Soc. Lon. IV, 45.
†Ibid, XXIII, p. 184.
‡Phil. Mag., 1803, XV, 325, pl. VI.

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Science, which was found in a creek emptying into the Ohio river. Dr. Harlan* gave it the name of Bos latifrons. A cast of the specimen was sent to Cuvier in France. Notwithstanding its size and locality Cuvier considered it to represent Bos priscus. Leidy in July, 1852, asked the attention of the members of the Academy to the fossil and Cuvier's determination of it, stating that it belongs to a species of bison and is with very little doubt distinct from the Bison priscus and should be called Bos latifrons. Again, in his memoir he states that Dr. Harlan was quite justifiable in proposing the name Bos latifrons for this animal. Leidy, however, in the same memoir gives a description and figure of the fossil with dimensions under the name of Bison latifrons.

The horn-core of this specimen was no less than 20½ inches in circumference at the base and 17½ inches at ten inches from the base. Only about one-half of the length of this horn-core was preserved. Judging from the figure given, one-fourth size, the core more nearly resembles the horn-core from Arizona than any other of which descriptions have been found, but these specimens do not appear to me to bear any resemblance to the horn-cores of our lately existing buffalo.

At the same meeting of the Philadelphia Academy noted Dr. Leidy exhibited a fragment of another skull and horn which must have belonged to a smaller animal. "The horn-core is relatively more conoidal and curved than in Bison latifrons." It was from Big Bone Lick, Ky., and probably indicates a distinct species for which the name Bison antiquus was proposed. †

Dr. Leidy, also, in his memoir directed attention to the fossil horn-cores described by Dr. Carpenter, of which a condensed statement follows, and stated that they appear to belong to the same species described by Harlan as Bos latifrons.

Dr. William M. Carpenter, of New Orleans, described in January, 1846,‡ some fossils collected by Mr. William Huff from the banks of the Brazos river, near San Felipe, Texas. Amongst them were remains of an "ox," consisting of the front-

*Harlan, Fauna Americana, p. 273.

†Proc. Acad. Nat. Sci., Phil., 1852, VI, p. 117. See also Memoir above cited.

‡American Jour. Science (2) I. p. 244, Art. XII, March, 1846.

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al bone of the skull and the greater portions of the two horn-cores and a single tooth. These bones were found in a gravelly deposit and were partially coated with a cemented mass of oxide or iron and pebbles and sand. The drawing accompanying the description shows the breadth of the frontal bone and the portions of the horn-cores preserved. These horn-cores are shown to extend outward and a little upward. The ends of each horn-core were broken off. The right horn-core measured two feet and the left one eighteen inches, and the distance between the broken ends including the frontal bone was 56 inches. The frontal bone between the horns was 14 inches in breadth, and between the external angles of the orbits 14¾ inches and between the internal angles of the orbits 11½ inches.

The bones of the horns are described as nearly round (cylindrical). The circumference at the base was 17 inches, and at a distance of 18 inches from the skull the circumference was 14½ inches. It was the opinion of Dr. Carpenter that the horn-cores when perfect must have been four feet in length each, and that with the addition of only one foot to each for the horny parts the total breadth between the tips of the horns must have been at least eleven feet.

In the "Natural History of the State of New York," DeKay* enumerates four species of fossil Bovidæ: Bos bombifrons Harlan, Bos latifrons Harlan, Bos pallassi De Kay and Bos moschatus Gadman (the musk ox). Of B. bombifrons Dr. Leidy says this species was established by Dr. Wistar in 1814 upon a part of a skull with both horn-cones nearly entire, found at Big Bone Lick, Kentucky. To this species Dr. Harlan gave the name of Bos bombifrons.†

In September, 1877, Prof. O. C. Marsh ‡described two new species of Bison, one B. ferox, from the lower Pliocene of Nebraska and the other B. alleni, also from the lower Pliocene of Nebraska. These were represented by well preservd horn-cores, now in the museum of Yale University, where, by the courtesy of Prof. Marsh I have been permitted to critcally examine them.

*Zoology Part I, p. 110.

†Fauna Americana, p. 271.

‡Am. Jour. Sci., XIV, No. 81, Sept. 1877, p. 252.

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Table of some of the Dimensions of Horn-Cores of extinct species of Bos or Bison found in Europe and America.
(In English inches and decimals.)

	Name, Locality and Authority.	Breadth between horn-cores.	Circumference of horn-cores.	Diameter.	Length.	Distance between tips.
1	Bos primigenius, Cuvier, cited by Dawkins, . .	12.8	12.9		27.9	32.5
2	" " Arpajon, France, " " " " . .	11.0		5.5		24.8
3	" " Scania, " " " " . .	12.01				28.0
4	" " Avon, n. Bath, Eng., Dawkins, ...		17.5		36.5	39.0
5	" " Clacton, Essex, Eng., Brown, cited by Dawkins, . .			6×5	36.0	
6	" " Herne bay, Eng., Dawkins, ...		18.85		39.0	
7	" " Crayford, Kent, Eng., ...		16.6		35.0	
8	Texas, U. S., Carpenter, Am. Jour. Sci., 1846, . .	14.0	17.0			56.0
9	Bison latifrons,† Ohio River,(Brown) Leidy, Acad. Nat. Sci., VI, 117 and Memoir	15.0	20.5			
10	Bison ferox, Nebraska, Marsh, Am. Jour. Sci., XIV, . . .			4.9	19.5+	
11	Bison alleni, Nebraska, Marsh, " " " " . . .			5.5		
12	Bos arizonica, Arizona, ...	?	17.5	6×5	24.0*	60*

*Estimated, †Bos latifrons Harlan.

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The horn-core of B. ferox, according to Prof. Marsh, indicates an animal much larger than the existing bison, having very powerful horns. He gives the following measurements: Length, when complete, over 500 millimetres, radius of the inner curve about 400 millimetres. The largest end has a diameter of 125 millimetres and the smaller at a distance of 300 millimetres measures 77 millimetres.*

Bison alleni has its greatest and least diameters near the base, 140 millimetres, and 110 millimetres, and at a distance of 300 millimetres toward the smaller end the diameters are 100 millimetres and 90 millimetres. Prof. Marsh also observes: "The discovery of these two lower Pliocene species of Bison suggests the probability that this form is a new world type, although it has generally been credited to the other hemisphere."

Comparing these two fossil cores with the cores of B. arizonica I find that the difference between them and the cores of B. arizonica are greater than between each other. Both B. ferox and B. alleni are longer in proportion to their thickness than in B. arizonica, and the curvature is greater.

For purposes of comparison of some of the chief dimensions of the B. primigenius of Europe and of the more closely related forms of America, I have prepared the tabulated statement.

THE SIGNIFICANCE OF THE FRAGMENTAL ERUPTIVE DEBRIS AT TAYLOR'S FALLS, MINN.†

By N. H. WINCHELL, Minneapolis, Minn.

The conglomerate at the celebrated geological locality of Taylor's Falls has been known since its first description by Owen. It has been described later by Kloos, Strong, Irving and by the writer, and recently been carefully examined by Mr. Berkey in the course of his mapping of the region for his thesis lately published in the American Geologist.

Dr. Owen considered the eruptive rock of later date than

*In the foregoing table I have given these measurements in their equivalents in English inches in order to facilitate direct comparisons.

†Read before the Minnesota Academy of Natural Sciences, Dec. 30th, 1897.

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the sandstones of the region. He had the idea that the igneous rock had been thrust up through the horizontal strata, and really did not entertain at all the later interpretation put upon the structure by Kloos. Mr. Kloos corrected Dr. Owen's explanation, showing conclusively that the sandstone was deposited upon the igneous rock as a debris of erosion after the igneous rock had cooled, and that at the bottom of the sandstone was a conglomerate composed almost entirely of pieces of the igneous rock. This view has been adopted by all subsequent observers. Irving often quoted this locality to show that the Keweenawan formation is unconformable beneath the horizontal sandstones and that a profound erosion interval separates the two formations.

At a meeting of the University Geological club, about a year ago, this conglomerate was incidentally under discussion in connection with a paper read by Mr. Berkey. From general taxonomic studies of the Keweenawan and its relations to the sandstones, published in 1895, the writer was strongly impressed with the probability that at Taylor's Falls were various interesting facts yet undeveloped by former observations, one of which would probably be the separation of the conglomerate into two conglomerates, each being at the bottom of one of the parts into which the Cambrian in the northwest is divisible, and the lower one separating the eruptives of the Keweenawan (as described by Irving), into two parts.

Since that, several important and interesting discoveries have been made, as follows, in the order in which they were brought out:

1. The first important fact is due to microscopical examination, viz: in some thin sections examined by Mr. Berkey, the rock from which they are derived is found to be a tuff or grit of eruptive materials. The parts are sub-angular and rounded, consist very largely of a highly doubly refracting mineral like epidote, of devitrified glass and of quartz. It is evident therefore that if this rock resulted from volcanic activity at the time of its formation, the fragments were wholly wrought over by some detrital action.

2. On visiting the place in company with Mr. Berkey he guided me to the spot at which this rock appears. It is at the corner of Government and West streets, about 200 feet

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above the river, spreading irregularly over an area of several rods. It shows plainly the structure of a sedimentary rock, with oblique stratification and banding, having an observed thickness of not more than ten feet. It lies on a coarser conglomerate or breccia, the general structure and dip being such as to throw them both below a great thickness of other igneous beds consisting of alternating trap and amygdaloid. The lower or conglomeratic portion of this fragmental is made up of large and small masses of trap, sometimes amygdaloidal and sometimes massive, having an observed thickness between 30 and 40 feet. This might easily be mistaken for a rough condition of the trap of the country, brecciated, etc., but there is more or less of the rock (2129) above described disseminated through it, indicating the action of oceanic and detrital forces during its accumulation. In other words, this coarse trap-boulder rock is of the nature of a conglomerate and lies below other trap beds.

3. Seeking evidence of the thickness and the extent of this lower conglomerate, we found a similar rock at one block west of the public school house, where only the fine-grained aspect is seen, and where it appears as if it had been broken mechanically and recemented by its own debris, making a fine-grained, nodular, hard rock, which rises three or four feet and is exposed about 20 feet east and west. A thin section of this rock shows essentially the same characters as that at the corner of Government and West streets, except that it contains more secondary silica and less epidote. In it are also developed acicular actinolites which lie in the position and have the form of wheat-sheaves, their extremities fraying and spreading out. That this structure here is due to secondary growth under the action of dynamic or some other force is evident, for these actinolite bundles lie in and penetrate secondary granular quartz, the fibres running frequently from one grain into another, or even piercing several grains.

We saw no further exposure of this conglomerate until we descended the hill southwardly to the railroad. Here can be seen both conglomerates. The upper one rises in a bluff where Upper Cambrian fossils are found in a dolomitic cement embracing boulder masses of trap, and the lower one is seen in the lower portion of the bluff and in a more limited

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surface exposure near the railroad at the level of the track. It here is coarse, composed mainly of trap masses, but has the same granular fragmental debris as a cementing material. The trap masses vary in color and texture.

4. From these outcrops, and from the known dip and strike of the igneous beds within which this trap-conglomerate is embraced, it can be inferred that the strike of the lower conglomerate is from NW. to SE. about coincident with that of the trap. As to its thickness, while we can affirm no more than was actually seen, we may infer from the topography throughout which the outcrops are distributed, that there is a greater thickness than 30 or 40 feet, and that 200 feet would be nearer the actual thickness.

This conglomerate is not known on the east side of the river, and its dip and strike cause it to occupy only a narrow belt extending diagonally across the southern portion of Taylor's Falls.

It is to be inferred, therefore, that at the date of the accumulation of this rock the ocean occupied the place of Taylor's Falls. That in the near vicinity were active or extinct volcanoes, the ejections of which contributed to the sedimentary accumulations. These may not have been distinctly volcanic emissions, but may have been eruptions from fissures, and the cooling lava may have spread so widely as to form extensive sheets. These lava sheets were immediately subjected to oceanic friction and disintegration. The glassy scoria was quickly broken and deposited as sedimentary material. The occurrence of grains of aporhyolyte in this grit shows that in these surface rocks the well known "red rock," so called, of the lake Superior region, was an important ingredient, and indicates that the traps that underlie this conglomerate at Taylor's Falls are structurally comparable with those associated with the red rock series of the northern part of the state. Still it is also certain that basic elements entered much more extensively into the accumulating conglomerate. The coarser and distinctly boulder-part of this stratum is composed almost entirely of basic material. This is to be accounted for by the immediate proximity of the basic traps of the formation which preceded the conglomerate, which are several hundred feet thick and which rise

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in perpendicular cliffs, as eroded by the St. Croix river, at several points in the near vicinity, forming the celebrated St. Croix dalles. The demolition of these older rocks by the ocean shore would furnish a coarse bouldery conglomerate which at a slightly later date, or at more distant or more sheltered points, would be buried under a finer tufaceous or gritty stratum, the product of gentler action. This succession seems to have formed the conglomerate and the overlying grit here described.

The significance of this fragmental and tufaceous member in the midst of the otherwise wholly igneous rocks of the Keweenawan, at Taylor's Falls becomes apparent when it is compared with what we know of this formation further north. About a year ago, in studying the rocks gathered at Duluth by the geological survey, it was found that a similar grit occurs there in the midst of the trap rocks, lying upon a large series of surface flows and derived from them, at the bottom of which is the chief gabbro mass of the region. It was also found that two conglomerates succeed each other, in the St. Louis valley, one containing eruptive materials and the other not. It was also found that the record of the deep well sunk for gas! at a few miles west from Duluth demonstrated two eruptive series separated by a grit or quartzyte and by other fragmental debris. At a later date it has been found that at several places on the north shore there is a conglomerate and quartzyte at the bottom of the upper portion of the trap series. This conglomerate indicates in several places a profound non-conformity. It succeeded, in time, the Animikie formation and the gabbro dikes of Pigeon point, and the aporhyolytes or "red rocks" which are associated with the gabbro. In short, about Grand Portage this break in the formation, separating the Animikie and the gabbro with its surface flows from the later traps is most clearly demonstrated. It has become our custom to designate the gabbro and its eruptive age Norian, and the overlying conglomerate and quartzyte, with the basic flows which succeeded them, Keweenawan; and we have been able to locate this conglomerate at several points between Duluth and Grand Portage. Thus it appears that in Minnesota, extending from Taylor's Falls to Grand Portage bay, the eruptive rocks which it has been customary

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to include in the Keweenawan are divisible into two great series separated by a period of quiet in the eruptive activities. During this period of comparative quiet was accumulated a conglomerate and a quartzyte which reached the thickness of several hundred feet.

What has now been said should be understood as referring to a stratum which at Taylor's Falls and elsewhere lies between two important series of trap sheets. It has no reference to the conglomerate which at Taylor's Falls has a dolomitic or arenaceous cement in which are found Lingula and Discina, indicating its Upper Cambrian age and which has been frequently mentioned by geologists. The accident that this later conglomerate lies directly upon the earlier, at one or two of the most favorable exposures, has hitherto confused the true relations, and has led to the belief that the whole conglomerate belongs to the Upper Cambrian. This was the view taken by the writer published in the geological survey report for 1881 (10th Rep. pp. 117, 118). The differences between the matrix of the lower conglomerate and that of the upper were pointed out, so far as they could be by field observations, but these differences were attributed provisionally to a hypothetical alteration which the bottom of the conglomerate was presumed to have suffered. It was not till the recent survey by Mr. Berkey that the entire separation of the lower from the upper was established.

But this chronologic and stratigraphic separation brings up another difficulty, viz: may not the lower conglomerate be of the nature of a flow breccia of the igneous rocks? This view is that taken by Mr. Berkey in his recent paper published in the American Geologist,* treating of the geology of the St. Croix dalles. It must be admitted that outwardly, when the upper surface of the conglomerate has been denuded by the removal of the overlying grit and tufaceous stratum, the rough and rounded masses that present themselves, making a somewhat hummocky appearance, might be attributed to the action of a cooled upper surface of a lava flow, brecciated and somewhat rounded by the crowding and friction of the still moving molten portion underneath. To the writer, however, the difficulties which such an inter-

*Vol. XX, pp. 345-383, Dec. 1897.

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pretation encounters are greater than in that which has been presented, viz:

1. The ocean was present at least immediately after the formation of the conglomerate, as evidenced by the collection and stratification of the overlying tuff.

2. The cement of the conglomerate is of eruptive debris, which, in several instances observed, is like the overlying tuff. This shows that the cement was accumulating at the time of formation of the conglomerate, and that therefore the ocean was present, and was very likely doing the same work as when later it spread the tuff over the conglomerate. The immediate proximity of the older trap, which may have risen in bold hills, will account for the coarseness of the lower portion of the stratum as compared with the upper.

3. In the overlying (Upper Cambrian) conglomerate are boulders and smaller fragments of an earlier conglomerate, and from their nature and the proximity of this lower conglomerate, it is necessary to refer such fragments to this conglomerate.

4. General taxonomic considerations, as already stated, point to the existence of a great fragmental stratum separating the Norian from the Keweenawan, and it is reasonable to look for it where a great valley of erosion, like that of the St. Croix, crosses the strike of those formations.

Still, until further examination shall show more fully the extent of this stratum and its nature, the question of its stratigraphic significance and importance may be held in abeyance.

THE HYPOTHESIS OF A CINCINNATI SILURIAN ISLAND.

By Arthur M. Miller, Lexington, Ky.

Dr. Keyes has recently* contended for the mythical character of the Paleozoic Ozark isle. The writer shares Keyes' skepticism, and desires to be included among those who dissent from the "old island hypothesis" as the usual method of explaining isolated areas of older formations peeping out from under newer upon the backs of broad dome-like uplifts.

*Science, new ser., vol. 7, pp. 588-589, Apr. 29, 1898.

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Our writers of geological text-books, following tradition, have without questioning accepted this island hypothesis. It seems to harmonize well with the theory of continental growth from a central nucleus by progressive elevations, and is in keeping with a general reluctance on the part of these and other writers to recognize in erosion the prime factor in bringing about the exposure of ancient formations. Thus Le Conte, while admitting that some such areas may have been uncovered by erosion, seems favorable to the "progressive elevation theory,"* and again he refers directly to the existence of a "large island in Devonian seas in the region of Cincinnati."† Scott accepts the Ordovician age of the Cincinnati arch‡ and the existence during Silurian and Devonian times of islands in this region.§

Dr. Newberry, as early as 1869, when state geologist of Ohio, attributed the exposure of Lower Silurian rocks in the southwestern part of the state to the uncovering action of erosion; but his successor, Prof. Orton, argued for the existence of the "Silurian Island."

Recently, also, Weller accepts without hesitation the old view of the former existence of all these islands and has them play an important rôle in the early Carboniferous seas.‖ In attempting to correlate with changes in physical geography, the faunal changes recorded in the fossils of the Mississippian series, a most kaleidoscopic shifting of land and water areas (reminding us of the "catastrophic oscillations" of Woodward) is assumed. With the meager evidence at command, it is hazardous to attempt such paleographic restorations. "Laurentian land" and "Appalachian land," somewhere in the regions usually assigned them, there may have been; Paleozoic sediments had to come from somewhere; but we believe the usual ground upon which the position and outlines of these have been deduced is open to question. Extensively denuded surfaces of moderate geological antiquity have been mistaken for slightly denuded surfaces of great geologic antiquity. Es-

*Elements of Geology, 4th ed., pp. 308-309, 1896.
†Op. cit. p. 341.
‡An Introduction to Geology, p. 378, 1897.
§Op. cit. pp. 386, 395,
‖Jour. Geol., vol. 6, pp. 303-314, Apr.-May, 1898.

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pecially mythical seem these alleged geologic islands and their including seas and oceans. "Ozark and Cincinnati isles," "Eurasian oceans" with "Northwest passages," "Osage seas" and "Waverly gulfs" form very pretty geographic terms and can be assigned places on a map. Like Kant's "islands of fancy" they may be given all the characters pertaining to existence *in intellectu;* but have they therefore had existence *in re?* Let us examine the evidence.

The existence of the Cincinnati island since Silurian (Upper Silurian) times has been inferred:

First and chiefly, from the present insular exposure of Ordovician strata on the summit of a broad dome or anticline. This exposure, a little over 13,000 square miles in extent and comprised within the states of Ohio, Indiana and Kentucky, has Cincinnati somewhat centrally placed within it. The summit of the dome, however, is in the vicinity of Lexington, and "Lexington uplift" would have been a preferable name to "Cincinnati arch."

Second, from indications of shallow water and shore conditions having prevailed around this area. The alleged indications are: (1) Thinning out of strata along margins of Silurian and Devonian, with overlap; (2) presence of conglomerates and breccias in these same situations; (3) ripple markings in the sandstones and limestones, and (4) traces of land vegetation.*

In regard to (1).—It is true that Devonian and Silurian sediments are very thin along the margins of this area, but they are also even thinner under cover of the Lower Carboniferous sediments, where these go over the lower portion of the arch between the Kentucky and Tennessee uplifts. On the other hand the Waverly shows no signs of thinning along the margins. In the alleged instances of overlap (one is known where Devonian Black shale rests directly upon Ordovician limestone and shale), the proof of an interval of subaerial decay between the two deposits is wanting, or at all events is not conclusive. Moreover the drill also reveals these same "'wants" southward under cover of the Lower Carboniferous sediments.

*On the presence of ripple marks, rain marks, mud cracks, etc., in the Cincinnati rocks the reader may also consult an article by N. W. Perry, in the American Geologist, IV., pp. 326-336, 1889. [Editor.]

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(2) Conglomerates and breccias.—These do exist, the former in the basal conglomerate of the Coal Measures outcropping in steep escarpments around the margins of the area and the latter in the Clinton and Corniferous limestones further up upon the flanks of the arch. But the conglomerate is composed of pure crsytalline quartz pebbles, which could not have been derived from the strata composing a Cincinnati island, and the breccias are not confined to the Clinton and Corniferous. Limestone pebbles have been found even in the lowest Cincinnati limestone upon the very summit of the present anticline.

(3)The same thing may be said of the ripple and wave markings. They occur in Ordovician as well as in later strata and seem to indicate that shallow seas were not infrequent phenomena in this region during all Paleozoic time.

(4) Plant remains.—The finding in the Clinton of Ohio of a supposed trace of land vegetation was long taken as confirmation of the "Silurian island hypothesis." Since, however, *Glyptodendron eatonense* has been proven to be a fragment of *Orthoceras*, we have only negative evidence there. The occurence of silicified wood in the Devonian Black shale at different points in Kentucky is as consistent with the sargasso sea theory of the shales deposition as shore deposition. One would expect to find water-logged timber upon the bottoms of sargasso seas.

Reviewing then the evidence, we cannot say indications of shallow water and shore conditions are so much more pronounced in post-Ordovician than in Ordovician strata of the Ohio valley, as to warrant the assumption that land first appeared in this region at the close of Ordovician time and has existed continuously there ever since.

Against this view considerable positive evidence may be cited.

First.—The present arrangement of the drainage controverts it. It is difficult to understand how two such rivers as the Ohio and Kentucky could have established themselves in their middle and lower courses squarely across this anticline, if the anticline were there first. But granted the antecedent character of the rivers and the arrangement is perfectly intelligible. Extending for 45 or 50 miles somewhat parallel with the

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axis of the anticline and a little to the eastward of it is the "Kentucky River fault." This fault exhibits a maximum displacement of about 300 feet. It shows every evidence of being contemporaneous in formation with the uplift. Only Ordovician strata are now involved in it. Upon the theory of the late Ordovician or early Silurian age of the Cincinnati anticlinal island, this is all the strata that could have been involved in it, and the fault must therefore have been a surface phenomenon in Silurian times, presenting an escarpment to the east of 300 feet. The Kentucky river strikes this fault at Boonesboro and turns southwestward, crossing and recrossing the line of the fault eight miles before it finally crosses to the west at Camp Nelson. If this fault were formed antecedent to the river and the country has suffered so little denudation as would be indicated by the bare removal of this three hundred foot escarpment, it must in all probability have presented a considerable face even after the Kentucky river was established, and we have the strange phenomenon of a river running up a slope of an anticline and deliberately attacking and breaching an escarpment nine times. If the river were antecedent to the fault or if the latter were not originally a marked surface phenomenon, we can understand how the river might adjust itself to the changing conditions as it found them, preserving a record of this in its diversion to the southwest.

Second.—The indications of a vast amount of denudation in this region renders it probable—almost certain—that the arch was formerly covered by all the latter formations up to and including the Carboniferous. Traces of the former presence of these formations are abundant. The Lexington Limestone (Trenton formation of the Kentucky survey reports) forms the surface rock on the summit of this dome over 1,060 square miles. It has here a thickness of 200 feet, with the top 975 feet above the sea. It constitutes by weathering the typical blue grass soil. Tongues and outliers of the Cincinnati (Hudson of the Kentucky survey reports) prove that this formation once covered the whole Trenton blue grass area. On the very summit of the arch a faulted outlier (a wedge-block between two faults) preserves middle Cincinnati (Hudson) sandstone. The fault escarpments have been entirely removed.

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Surrounding the Lexington limestone area comes the Cincinnati blue limestone area, about 12,000 square miles in extent. The thickness of the formation is from 600 to 800 feet. Outliers of Niagara and Corniferous limestone lie far within the boundaries of this region. One of these, constituting Jeptha knobs in Shelby county, Kentucky, on the western limb of the anticline, lies approximately half way between the internal and external boundaries. The hight of the Corniferous upon the top of these knobs is between 1,200 and 1,300 feet above sea level—high enough to peep over the arch at its highest point. This proves that the formations up to and including the Corniferous went over the whole combined Lexington and Cincinnati areas.

A little nearer the margin of the Cincinnati area, but still well up toward the crest of the arch, where it begins to pitch southward under the Devonian and lower Carboniferous, is Burdett's knob, in Garrard county, Kentucky. This is also a faulted outlier. It rises to a hight of 1,090 feet above tide and preserves the remainder of the Devonian (the Black shale) with a thin capping of Lower Carboniferous (Waverly). By the same reasoning it seems impossible to escape the conclusion, that the Lower Carboniferous went over the area in question; and if the Lower Carboniferous why not the Upper? Outcropping all around the margins of both the Eastern and Western coal fields is the great basal conglomerate. It rises into great cliffs, which for the Eastern field reach an altitude of 1,400 feet where they overlook the central blue grass counties of Kentucky. A restoration of the air lines of this formation easily carries it over this region, and over the very summit of the Lexington dome it one time must have gone.

We may form some idea of how high this would have made our arch had it not been denuded. Green River knob, in Pulaski county, Kentucky, on the summit of the arch where is sinks to its lowest level before rising to the Tennessee maximum, is 1,800 feet above the sea. It preserves on its summit an outlier of Kaskaskia sandstone just beneath the Coal Measures. As has been noted by Prof. Shaler, from the top of this knob on any clear day may be seen the outliers of the Eastern and Western coal fields, here some 85 miles apart. Undoubtedly the Coal Measures once extended over southern

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Kentucky. The base of them, therefore, would have had an elevation of 1,800 feet on the crest of the anticline, supposing it were in existence. The base of the knob in Devonian Black shale has an elevation of 1,000 feet. The formations between this and the top of the Lexington limestone will add up about 800 feet, making 1,600 feet for the thickness of the stratigraphic sequence between this limestone and the base of the Coal Measures. Place this series upon the top of the denuded blue grass dome and we have at least 2,600 feet as its restored hight. To this must be added whatever thickness of Coal Measures went over.

Of course it is not unlikely denudation has been accomplished *pari passu* with elevation and these extreme hights have never been attained. It is also possible the arch in its present condition is of recent geological development and may have been formed subsequent to much of the denudation.

There seems to be a striking parallelism recorded in the history of the Ozark and Cincinnati uplifts. The cycles of erosion in each seem to have been contemporaneous, affecting indeed the intervening country as well. The differences seem to have been more in the extent of the vertical movements than in the time of them. The lowest strata exposed in the gorge of the Kentucky river, where it crosses the crest of the uplift, is lowest Ordovician or Upper Cambrian. The most recent elevation, as recorded by the hight above the present channel of the old river deposits, is between 300 and 400 feet. Had the elevation been greater there seems no reason to doubt but we might have had Algonkian strata exposed, just as in the Ozark uplift.

Keyes' views that the last uplift took place in Tertiary times are endorsed by Marbut, Davis, Griswold and others. Campbell, who studied the gravels, sands and clays covering the uplands in the vicinity of the Kentucky river where it emerges from the Eastern coal field, considers them deposits of an upland river thrown down where its gradient changed upon entering a base-leveled plain. He favors the Tertiary age of these deposits and provisionally colors them as Neocene on the map. This would assign to late Tertiary the date of the last upward movement in this region.

In the light then of all the evidence cited:—that afforded

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by the rivers in their present arrangement and past behavior; the disposition of the formations in encircling belts skirted by detached outliers; the positive evidence of fault scarp removals;—we may conclude that denudation and not lack of deposition of the later formations is the true explanation of surface Ordovician in the Ohio valley; and that the "Cincinnati Silurian island" must henceforth take rank as a geologic myth.

WEATHERING OF DIABASE NEAR CHATHAM, VIRGINIA.*

By THOMAS L. WATSON, State Geol. Survey, Atlanta, Ga.

Introduction.†

While visiting Virginia during the late summer and early fall of 1897, the writer had occasion to study and collect specimens of the so-called Mesozoic "trap rocks," which have been noted in the form of sheets and dikes throughout the most of the Atlantic border region.

Notwithstanding the rather complete knowledge of the geological features and chemical composition of these rocks, but few writers have touched on their disintegration and decomposition. Wherever studied along the Atlantic border region, their remarkable uniformity has been noted, varying but little in mineral and chemical composition. Futhermore, the specific gravity determinations collected from various sources and quoted by professor James D. Dana‡ further illustrate the striking uniformity in these rocks, the limits of which are given as 2.94 and 3.16.

*The writer wishes to acknowledge his indebtedness to the authorities of the United States National Museum for kindly allowing him the opportunity to work up the material. He is especially indebted to professor Geo. P. Merrill, Head Curator, Dept. of Geology, in the Museum, for so generously placing at his disposal facilities and equipment for the prosecution of the work, as well as for the constant suggestions given throughout. To Dr. E. C. E. Lord, I am indebted for many suggestions and aid.

†The results of this investigation are based upon the methods and principles so clearly set forth by Dr. George P. Merrill in his numerous valuable publications on rock weathering. See Bull. G. S. A., Journal of Geology, Treatise on "Rocks, Rock-Weathering and Soils."

‡Am. Journ. Science, 1873, (3. S.) 6, 105.

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Although the similarity in the above respects are very close, the same rocks, according to locality, offer wide differences in their final products of decay. These differences are not without their importance and significance, from an economic as well as a scientific standpoint.

Locality. The material, from which the results given below were obtained, was collected from a series of dikes of considerable though variable widths, in the southern and central part of Pittsylvania county, Virginia, a few miles west of the county court house. Here the dikes break through the old crystalline schists and gneisses of the Piedmont plateau, but when traced for a short distance to the east and south they are found intersecting the Triassic shales and sandstones of the "Danville area."*

The dikes are numerous throughout the county, and good exposures frequently occur, the best of which are seen in and along the cuts of the Southern railway. Generally, they can be traced with considerable accuracy over the surface by their weathered products, mostly in the form of boulders, which, on account of their dark color and hardness, are called "niggerheads." The extreme depth in decay of both dike and country rock, renders, even in the deepest cuts, the differentiation of the contact between the two extremely difficult and often impossible.

Field Character of the Rock. Texturally, the rocks here studied are of two kinds. The first is a very uniformly coarse granular rock of a dark gray color, with a decided greenish cast, and a more or less greasy lustre. In the fresh and unweathered hand specimen, feldspar, augite and olivine can be detected with the unaided eye.

The second is a more homogeneous fine grained rock, of a dark steel gray color, in which only feldspar and augite are recognizable with the naked eye.

The final products of weathering are apparently the same for the two rocks, and therefore, cannot be differentiated from each other in the field. In each case, the residue is a tough clay of a bright red color. Weathering in concentric layers, so generally characteristic of basic eruptives, is beautifully

*For a description and extent of this area, see Correlation Papers, Newark System. Bull. No. 85, U. S. G. S., p. 22.

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shown in this locality. Between the two extremes are noted many stages of decay. Boulders of variable sizes and in different stages of decay are imbedded and distributed throughout the mass of incoherent red clay. From the beginning in weathering to the stage where the minerals are entirely decomposed, but still held intact, the layer of shelly structure is well shown in the boulders.

While the color of the decay is prevailingly red, frequently a mottled gray color is seen, and is especially noticeable in the boulders, which have not reached the limit in decomposition, but those in which the shelly structure is still shown.

Petrographic Features of the Rock.

TABLE NO. 1.

Bulk analysis of Fresh and Disintegrated Diabase from Chatham, Virginia.

CONSTITUENTS.	I	II	III	IV
Silica SiO_2	45.73	47.87	37.09	52.06
Alumina Al_2O_3	13.48	14.43	13.19	13.67
*Iron Fe_2O_3	11.60	11.55	35.69	15.97
Lime CaO	9.92	10.45	0.41	8.15
Magnesia MgO	15.40	10.58	0.57	5.01
Soda Na_2O	3.24	3.47	1.75	3.36
Potash K_2O	0.47	0.61	0.33	0.86
Water H_2O	0.94	1.82	11.83	1.05
Total	100.78	100.78	100.86	100.13
Specific gravity	3.026			2.953

I. Fresh olivine diabase rock.
II. Partially weathered olivine diabase rock.
III. Decomposed olivine diabase rock.
IV. Fresh quartz diabase rock.

The fresh rock (see I in the above table) is a coarse granular admixture of plagioclase feldspar, augite and olivine, with accessory magnetite. Biotite, chlorite and serpentine occur as secondary minerals resulting from alteration. The structure is characteristically ophitic, showing in a marked degree the lath-shaped feldspars with the interstices filled

*All the iron is calculated as Fe_2O_3, which necessarily increases the summation of the results, inasmuch as some ferrous iron is present in the rocks.

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with the augites and olivines. The structure and mineral composition places the rock at once among the diabases, and on account of the large amount of olivine it is definitely classed as an olivine diabase.

The Augite occurs in large crystals with indistinct crystal outline. Sections cut parallel to the plane of symmetry show a very perfect cleavage. The pleochroism of some sections is fairly strong. **a**=reddish-brown, **b**=pale greenish-yellow, **c**=blue-green. Maximum extinction angle measured against the prismatic cleavage **c**: c=47°. Inclusions of magnetite are common in the augite crystals. The augite was separated from the other minerals by means of Thoulet's heavy solution and further by a magnet and lens to obtain particles as free from magnetite inclusions as possible. These were analyzed with the following results. (See I in table).

Table No. 2.

Analysis of Augite.

CONSTITUENTS.	I	II	III	RATIO OF I	
Silica SiO_2	48.83	48.80	49.33	.801	.801
Alumina Al_2O_3	4.41	4.14	9.15	.043	.043
*Iron Fe_2O_3	10.01	12.36	0.27	.125	
			FeO 9.05		.918
Lime CaO	20.51	19.49	16.36	.366	
Magnesia MgO	17.11	14.33	14.58	.427	
Soda Na_2O		H_2O 0.88	0.55		
Potash K_2O			0.19		
			Ign. 0.25		
Total	100.87		99.73		
Specific gravity...	3.232				

RO: R_2O_3:SiO_2=21:1:19

I. Olivine diabase from near Chatham, Virginia.

II. Analysis of an augite given by Hintze C. Handbuch der Mineralogie, 1893, II, p. 1107, No. CXII. Quoted from Lemberg, Zeitschr. d. geol. Gesch. 1877, 29, 495.

III. Analysis of diallagic augite in hypersthene diabase, from Culpepper county, Virginia. See Campbell & Brown, Bull., G. S. A., 1891, 2, p. 344.

The specific gravity of these fragments was 3.232.

*All iron calculated as Fe_2O_3. Assuming it all to be in the form of FeO, the results then become 10.01 per cent. Fe_2O_3=9 per cent. of FeO - giving a total of 99.86 per cent. for the analysis.

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Table No. 3.

Analysis of Feldspar.

CONSTITUENTS.	I	II	III	IV	RATIO OF II
Silica SiO_2	49.65	55.345	55.20	51.40	.922
Alumina Al_2O_3	24.49	27.299	28.60	30.98	.267
Iron Fe_2O_3	5.98			0.22	
Lime CaO	11.02	12.284	10.64	13.40	.219
Magnesia MgO	4.31			0.45	
Soda Na_2O	*4.55	5.072	5.55	2.85	.081
Potash K_2O				0.39	
Total	100.00	100.00	99.99	99.69	
Specific gravity	2.697	2.697	2.695.		

$\overbrace{R_2O}$: $\overbrace{RO}$: R_2O_3: $\widetilde{SiO_2}$ = 1:2:3:11.

I. Olivine diabase from near Chatham, Virginia.

II. No. I calculated to an iron and magnesia free basis.

III. Theoretical calulation for a feldspar corresponding to $Ab_8\ An_9$.

IV. Analysis of feldspar in hypersthene diabase from Culpepper county, Virginia. See Bull. G. S. A., 1891, 2, p. 343. (Campbell & Brown.)

Feldspar. A chemical analysis of the feldspar which was separated from the other minerals in the same way as the augite, indicates a basic plagioclase which is shown to correspond to labradorite, whose albite-anorthite ratio is Ab_8An_9 (See 3 in table). The optical properties are in accord with and confirm the chemical analysis. Extinction angle measured on M=∞ P$\breve{\infty}$ (010) gives 22°. Inclusions of magnetite and some augite are common in the feldspar. A quantitative separation of this mineral from the others shows that the entire rock is made up of 32.10 per cent of feldspar.

The Olivine occurs in large crystals with fairly distinct crystal outline. Abundant inclusions of magnetite are common. This mineral has suffered in some cases considerable alteration into serpentine and chlorite.

No. 2 (See bulk analysis, page 87) represents the first stage in weathering of 1, and contains the same minerals with a further development of secondary products. The olivines indicate a somewhat advanced stage of decay, shown by the iron sesqui-oxide covering to a more or less extent the crystals,

*Calculated by difference.

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TABLE No. 4.

Table showing the Relative Amounts of Material Soluble in Hydrochloric Acid of Different Strengths, all other Conditions remaining Constant.

	I				II.				III.				IV.		
Constituents.	1:1 by vol	N.	N \| 2	N \| 4	1:1 by vol	N.	N \| 2	N \| 4	1:1 by vol	N.	N \| 2	N \| 4	1:1 by vol	N.	N \| 2
Alumina Al_2O_3	10.26	9.96	9.10	8.18	11.80	11.12	10.93	8.77	10.65	9.20	8.22	6.87	7.76	6.08	5.99
Iron Fe_2O_3	8.83	8.65	8.75	7.88	6.50	6.13	5.83	5.51	33.61	31.76	28.25	25.34	10.96	10.92	10.60
Lime CaO	4.90	4.63	4.37	3.55	5.15	4.75	4.49	3.49	0.13	0.03	0.02	0.01	3.89	2.88	2.61
Magnesia MgO	8.87	8.76	8.65	8.47	4.60	4.04	4.28	3.72	0.31	0.11	0.20	0.09	2.22	1.65	1.49
Total	32.86	32.00	30.87	28.08	28.05	26.04	25.53	21.49	44.70	41.10	36.69	32.31	24.83	21.53	20.69
Average	30.95				25.28				38.70				22.35		

Coarse grain { I. Fresh olivine diabase rock. II. Partially altered olivine diabase rock. III. Decomposed olivine diabase rock.

Fine grain.— IV. Fresh quartz diabase rock.

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which is a result from the breaking down of the iron in the olivine.

No. 3 (See bulk analysis, page 87) is the completely weathered product of No. 1, which under the microscope is seen to be a highly ferruginous mass in which some silicate minerals can be noticed but not identified. However, after removing the iron stains by dilute acid, undecomposed grains of feldspar, augite and magnetite are clearly recognizable.

No. 4 (See bulk analysis, page 87) is from an adjacent dike, and differs somewhat from No. 1 in mineral composition. It is a fine-grained rock with a somewhat less characteristic ophitic structure. The essential minerals are augite and plagioclase feldspar with considerable quartz, which is probably in quantity sufficiently large to warrant the name "quartz diabase." The accessory minerals are hornblende, magnetite, biotite, pyrite, chlorite, serpentine and calcite.

Probably the most interesting feature of this rock petrographically, is the presence of an intergrowth of quartz and feldspar, forming a micrographic structure. The same structure has been noticed by Dr. Adams* in some of the Canadian diabases found to the north of the Island of Montreal.

Mechanical Analysis of Decayed Rock.

In order to more accurately indicate the physical conditions of the decayed product, and at the same time, point out to some degree, the physical changes in the degeneration of this rock, a complete mechanical† analysis has been made yielding the results given below.

The material analyzed does not represent the final decayed product, or soil, but is the outer decayed portion of one of the small boulders found scattered through the mass of incoherent clay. The decayed portion was still coherent, fairly firm and intact, but crumbled with considerable ease under pressure in the hand. In color, it was a bright orange yellow with a striking resemblance to one of the bright yellow colored

*See, Report on the Geology of a portion of the Laurentian area lying to the north of the Island of Montreal, Geol. Sur. Canada, Annl. Rept. 1896, part J, Vol. VIII, pp. 136-137.

†I am indebted to Mr. R. S. Hosmer of the Division of Soils, U. S. Department of Agriculture, for the analysis.

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ochres. A close examination revealed a spongy mass of iron sesqui-oxide, through which was distributed a perfect network of white kaolinized masses of the original feldspar. To the unaided eye the mass seemed thoroughly decomposed without any trace of the original silicate minerals preserved, but after removing the iron oxide by continued digestions with very dilute hydrochloric acid, and the residue subsequently examined under the microscope, considerable traces of both undecomposed feldspar and augite were distinctly recognizable, with surprisingly large quantities of magnetite. Apparently, the magnetite was in as fresh a condition and in as large quantities as in the fresh and unaltered rock.

	DIAMETER IN MM.	CONVENTIONAL NAMES.	PER CT.*
(1)	2 — .1	Fine gravel.	0.00
(2)	1 — .5	Coarse sand.	3.21
(3)	.5 — .25	Medium sand.	13.10
(4)	.25 — .1	Fine sand.	15.39
(5)	.1 — .05	Very fine sand.	23.49
(6)	.05 — .01	Silt.	23.98
(7)	.01 — .005	Fine silt.	4.16
(8)	.005 — .0001	Clay.	14.20
		Total matter	97.53

Nos. 2, 3 and 4 show clearly to the unaided eye the compound character of the mass, and when examined under the microscope, although the iron oxide masks to a large extent the reaction, distinct particles of the undecomposed silicate minerals with an abundance of magnetite are to be seen. In No. 5 the decayed products become more differentiated into kaolin and ferrite (iron oxide), with the usual amount of magnetite and some of the undecomposed silicate minerals still discernible. Nos. 6 and 7 represent highly colored ferruginous masses in which a slight sprinkling of the feldspar, augite and magnetite, can still be recognized, to a very much less degree, however, in No. 7 than in No. 6. No. 8 is a deep buff colored mass of fine clay showing no trace of the original minerals whatsoever.

Chemical Analyses and their Discussion.

Below are given three tables of analyses indicating the

*These residues were dried over the steam-bath and weighed without ignition.

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chemical nature and relationship of the same rock in as many stages of weathering.

Recalculating the analyses in columns I and III, in each of the three tables, on the basis of 100, and assuming one of the constituents as a constant factor, the results given in columns VII, VIII and IX are obtained.

"A."

Calculated Loss of Material in the Fresh and Partially Decomposed Rock.

CONSTITUENTS.	Fresh Olivine diabase		Partially Decomposed Olivine diabase		Calculated to total of 100.		Calculated amounts saved and lost.		
	I	II	III	IV	V	VI	VII	VIII	IX
	Bulk analysis.	Analysis of portion soluble in N/2 HCl and Na_2CO_3.	Bulk analysis.	Analysis of portion soluble in N/2 HCl and Na_2CO_3.	Fresh rock.	Partially decomposed rock.	Percentage loss for entire rock.	Percentage of each constituent saved.	Percentage of each constituent lost.
SiO_2	45.73	12.78	47.87	Not det.	45.38	47.49	0.99	97.81	2.19
*Al_2O_3 .	13.48	9.10	14.43	10.93	13.38	14.32	0.00	100.00	0.00
Fe_2O_3 ..	11.60	8.75	11.55	5.83	11.51	11.46	0.79	93.09	6.91
CaO	9.92	4.37	10.45	4.49	9.84	10.37	0.15	98.47	1.53
MgO ...	15.40	8.65	10.58	4.28	15.28	10.50	5.47	64.19	35.81
Na_2O. ..	3.24	Not det.	3.47	0.91	3.21	3.44	0.00	100.00	0.00
K_2O	0.47	"	0.61	0.45	0.47	0.61	0.00	100.00†	0.00
H_2O	0.94	0.94	1.82	1.82	0.93	1.81	0.00	100.00†	0.00
Total ...	100.78	44.59	100.78	28.71	100.00	100.00	‡7.40		
		31.81							

The special features to be noticed in this table are: (1), The relative amounts of material in the two rocks soluble in dilute hydrochloric acid, which are given as 31.81 per cent for the fresh rock, and 28.71 per cent. for the partially altered; the fresh rock yielding, therefore, the largest amount of extract. (2), An assumption of almost double the amount of water in column III as in column I; and (3), a slight percentage loss for the silica, iron and lime, with a rather marked loss in the magnesia, amounting to 35.81 per cent, yielding a total loss for the entire rock of 7.40 per cent, the alumina being the con-

*Alumina is taken as the constant factor in the above calculations.

†Gain.

‡Per cent.

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stant factor and serving as the basis of calculation. A slight gain is noted in the potash. This may in all probability be due to error in analysis, since the amount of this constituent found in the rock is scarcely more than appreciable and renders the results, therefore, somewhat unreliable.

Apparently, the change noted in the above table, in passing from the fresh to the partially altered rock, has been principally one of hydration. A slight oxidation, however, has taken place in the olivines, revealed under the microscope in the slight iron stains, and restricted entirely to this mineral wherever noticed in the slide. The only appreciable loss for any of the constituents is in the magnesia, which has been wholly derived from the breaking down of the olivines, and is, presumably, the result of the leaching action of percolating waters.

"B."

Calculated Loss of Material in the Partially and Wholly Decomposed Rock.

CONSTITUENTS.	Partially altered Olivine diabase.		Decomposed Olivine diabase		Calculated to total of 100.		Calculated amounts saved and lost		
	I	II	III	IV	V	VI	VII	VIII	IX
	Bulk Analysis.	Analysis of portion soluble in N/2 HCL and Na_2CO_3.	Bulk Analysis.	Analysis of portion soluble in N/2 HCL and Na_2CO_3.	Partially altered rock	Wholly decomposed rock.	Percentage loss for entire rock	Percentage of each constituent saved.	Percentage of each constituent lost.
SiO_2.....	47.87	Not det.	37.09	12.72	47.49	36 77	35.57	25.08	74.93
Al_2O_3...	14.43	10.93	13.19	8.22	14.32	13.08	10.07	29.58	70.42
*Fe_2O_3..	11.55	5.83	35.69	28.25	11.46	35.39	0.00	100.00	0.00
CaO.	10.45	4.49	0.41	0.02	10.37	0.41	10.23	1.25	98.75
MgO	10.58	4.28	0.57	0.20	10.50	0.56	10.30	1.72	98.28
Na_2O....	3.47	0.91	1.75	1.00	3.44	1.73	2.87	16.30	83.70
K_2O.....	0.61	0.45	0.33	0.20	0.61	0.33	0.49	17.29	82.71
H_2O.....	1.82	1.82	11.83	11.83	1.81	11.73	0.00	100.00†	0.00
Total ...	100.78	28.71	100.86	62.44	100.00	100.00	‡69.53		
				49.72					

*Iron is taken as the constant factor in the above calculations.

†Gain.

‡Per cent.

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Table B shows the relationship existing between the partially and wholly decomposed rock. It is noteworthy, that a very much larger percentage of material has been dissolved by dilute acid in the decomposed than in the partially altered rock. This is clearly the result of the oxidation of the ferrous to the ferric iron, and the retention of the oxidized product, since the iron has remained more nearly constant than any one of the other constituents. Of the individual constituents, 74.93 per cent of the silica, 70.42 per cent of the alumina, 98.75 per cent. of the lime, 98.28 per cent of the magnesia, 83.70 per cent of the soda, and 82.71 per cent of the potash have disappeared, equivalent to a loss of 69.53 per cent for the entire rock. The calculations in tables B and C are made on a Fe_2O_3 constant basis. Attention is here called to the unusually large percentage loss for the entire rock, which is rendered excessive by the very small amounts of silica and alumina retained. The loss in silica can be readily explained

"C."

Calculated Loss of Material in the Fresh and Decomposed Rock.

CONSTITUENTS.	Fresh Olivine diabase		Decomposed Olivine diabase		Calculated to Total of 100.		Calculated amounts saved and lost.		
	I	II	III	IV	V	VI	VII	VIII	IX
	Bulk analysis.	Analysis of portion soluble in N/2 HCL and Na_2CO_3.	Bulk analysis.	Analysis of portion soluble in N/2 HCL and Na_2CO_3.	Fresh rock.	Decomposed rock.	Percentage loss for entire rock.	Percentage of each constituent saved.	Percentage of each constituent lost.
SiO_2....	45.73	12.78	37.09	12.72	45.38	36.77	33.41	26.37	73.64
Al_2O_3...	13.48	9.10	13.19	8.22	13.38	13.08	9.11	31.81	68.19
*Fe_2O ..	11.60	8.75	35.69	28.25	11.51	35.39	0.00	100.00	0.00
CaO	9.92	4.37	0.41	0.02	9.84	0.41	9.71	1.32	98.68
MgO....	15.40	8.65	0.57	0.20	15.28	0.56	15.09	1.19	98.81
Na_2O ...	3.24	Not det.	1.75	1.00	3.21	1.73	22.64	17.54	82.46
K_2O	0.47	"	0.33	0.20	0.47	0.33	0.35	22.69	77.31
H_2O	0.94	0.94	11.83	11.83	0.93	11.73	0.00	100.00†	0.00
Total ...	100.78	44.59	100.86	62.44	100.00	100.00	‡70.31		

*Iron is taken as the constant factor in the above calculations.

†Gain.

‡Per cent.

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on the grounds that the change in the rock has been essentially chemical. Since no free quartz is present in the rock, the silica has been wholly derived from the silicate minerals, which as fast as liberated was, in great part, dissolved by the water present and removed. The proportions of lime and magnesia removed are about equal and are greater for these two than for any other constituents in the rock. As is most generally the case, an increased loss in the soda over that in the potash is shown. The marked increase noted in the water is what would be expected.

Table C compares the fresh with the decomposed rock. Here, again the analyses show a total loss of 70.31 per cent, or nearly two-thirds of the original material. The loss includes 73.64 per cent of the silica, 68.19 per cent of the alumina, 98.68 per cent of the lime, 98.81 per cent of the magnesia, 82.46 per cent of the soda, and 77.31 per cent of the potash. Such a large percentage loss for the entire rock is very unusual for silicious crystallines, as professor Merrill* has pointed out from all available analyses that this loss rarely amounts to more than 50 per cent of the total rock mass. In the majority of cases, however, the decomposed product analyzed, had not reached, or even closely approximated to its limit in chemical decay, for which some allowance and recognition must be made.

A notable example is cited by professor Merrill† in the analyses of fresh and decomposed basalt from Crouzet, in the Haute Loire, France, where the total loss nearly equals that shown here, but differing essentially in an unusual loss in the iron while the alumina remains constant, which is just reversed for the same two constituents in the Virginia rocks. The excessive loss in silica has been explained in the discussion under table B. Of all the constituents, the magnesia has been removed in the largest quantity. The removal of this constituent finds a ready explanation in the fact that it is mainly derived from the olivine. The weathering of olivine in the presence of water, oxygen, and carbonic acid would naturally result in the formation of carbonates, silica, and the

*See, Treatise on "Rocks, Rock-Weathering and Soils, 1897, p. 324.

†Ibid, p. 223.

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sesqui-oxide of iron; the magnesium carbonate being soluble in the carbonated waters would be carried off in solution.

The table shows that 44.59 per cent of the fresh rock and 62.44 per cent of the decomposed are soluble in dilute hydrochloric acid and sodium carbonate solutions. Furthermore, that in passing from the fresh rock to the decomposed the total amount of water has very greatly increased.

The conditions, under which the degeneration of the rock here studied has taken place, indicate, that they have been essentially of the nature of chemical decomposition rather than of mechanical disintegration. Evidently, then we have a rock whose decomposition is practically complete accompanied by a total loss of nearly two-thirds of the original material. While this loss, so far as data are available, is unusually large, it is probably what would naturally follow under conditions where the process is approximately complete and the forces involved are mainly chemical rather than mechanical. Clearly, the increased loss in magnesia indicates that the olivines were the first of the rock constituents to yield to the agencies of decay, the feldspar and augite proving the most refractory. This order has been shown by microscopic study, which finds confirmation in the chemical analyses.

With the above exceptions, the results and conclusions in general, closely agree with those reached by others in such cases. They point conclusively to the changes that have taken place in the decomposition of the rock being principally those of hydration and oxidation.

Order of Decay in the Component Minerals.

A microscopic study of the thin sections representing several successive stages in the rock decay, determined the least and most refractory of the minerals under the meteoric conditions for that locality.

However, tests were made on several portions of the fresh and decayed material with reference to the order of the solubility of the minerals in dilute acid. Also, to ascertain if possible what relation, if any, existed between the weathering under the natural conditions and that of solution.

The material was partially powdered and passed through a 40 mesh sieve, in order to secure grains of a uniform size,

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though precaution was taken not to reduce the grains fine enough to destroy their individuality any more than was possible. Portions were then digested on a water-bath, kept at a strong ebulition, in a covered dish, for several weeks with dilute hydrochloric acid, fresh quantities of which were added from time to time. A microscopic examination was made each time, after pouring off the extract, with the following results.—None of the mineral grains could be recognized as olivine after the digestion. This would indicate that the olivine had been dissolved and was the first mineral to yield to solution, and therefore the most susceptible. A thin section of the rock showed that the olivine had been altered in an appreciable degree to serpentine. Of those minerals recognized under the microscope, the feldspar proved the least resistant. Particles of various sizes were noted, but generally only small fragments of the original grains were left, which evidently suggested that a part of the fragments of the feldspar had been entirely broken down by solution. Usually the largest grains were either partially or wholly covered with an opaque material, taken to be kaolin, which would probably account to some extent for their more refractory nature. While, on the whole, the augite grains were appreciably reduced and showed marked etching from solution, it proved the most refractory of the essential minerals in the rock. So far as could be seen the magnetite underwent but little change from solution.

Apparently, the above results are in full accord with the mineral decomposition as shown under the natural conditions. That is to say, the decay, in this special case, seemingly follows, very closely, the order of solution of the various minerals.

The extent to which investigation in this direction has been carried, probably shows the opposite order of mineral decay in rock weathering to be of a more frequent occurrence and therefore more general.

The ferro-magnesian silicates, and especially those composed principally of the protoxides of the basic elements, such as iron and magnesia, are more susceptible to decomposition than the feldspars, owing to the readiness with which they are oxidized. Professor Merrill* states, that, "The evidence

*See, "Rocks, Rock-Weathering and Soils," 1897, p. 234

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bearing upon the relative durability of the various minerals constituting rocks is, however, quite conflicting and unsatisfactory." The results are probably, to a very large degree, controlled by local conditions. Cases are cited by professors Dana* and Merrill† among basic rocks, where the feldspar was the first mineral to yield to the atmospheric agencies.

Amounts of Material Soluble in Different Strengths of Hydrochloric Acid.

As the heading of table signifies, the results herein tabulated were obtained under as nearly the same conditions as was possible, varying only the strength of acid. In each case, approximately .5 of a gramme of the finely powdered rock was accurately weighed off and used. These weighed portions were digested in closely covered dishes with 100 C. C. each of the various strength acids, for three hours on a water-bath, brought to a strong ebulition and maintained throughout the digestion. They were then filtered and the filtrates subsequently evaporated to complete dryness in order that any soluble silica might be rendered insoluble.

The acids used were carefully and accurately prepared from hydrochloric acid of 1.20 specific gravity. The strength 1:1 by volume, meaning 50 C. C. of 1.20 specific gravity acid to 50 C. C. of distilled water—at ordinary temperature. The normal, half normal, and quarter normal strengths, meaning the whole, half and quarter molecular weight respectively of 1.20 specific gravity acid dissolved in one litre each of distilled water.

While the results, probably, have not been carried far enough to warrant any very definite statement, they are, I believe, highly suggestive and of some interest. No limit was reached where the extracts remained approximately the same for any two acids of nearly equal but varying strengths, but the difference in each case is appreciable and quite noticeable. It would be expected that where all other elements of condition remained fixed and constant, that a point would be reached where a maximum extract would be found, corresponding to a certain strength acid.

*Rep't. Wilkes Exploring Expedition, Geology, 378.
†Bulletin U. S. G. S., No. 110, 1894.

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Loughridge* has shown this to be true in the case of soils, and further pointed out a limit as to time, with reference to the amount of soluble material removed by digestion.

Turning now to the table, we find of the constituents determined, the alumina shows the greatest variation, with probably the lime next, although, in most cases, the iron indicates equally as great a variation.

The magnesia remains fairly constant for the same rock in I and II, while IV shows a wide variation, except when the maximum and minimum strength acids are compared.

Undoubtedly, some importance can be attached to the presence of the large amount of olivine in the first two rocks, and the readiness with which this mineral is dissolved by hydrochloric acid. It seems fair to assume, therefore, that the uniformity in the magnesia determinations can be accounted for in part on this basis. This is apparently more fully warranted when we notice the variation in this constituent to be equal to that of any other in rock IV, which is an olivine free rock.

Each residue was carefully examined under the microscope, after filtering off the extract, and an abundance of undecomposed silicate minerals was noticed in all, generally in a highly etched condition. With the exception of the strongest acid used (1:1), the residues from the remaining acids indicated as great an abundance of magnetite as in an untreated portion of the same rock, which so far as could be detected showed apparently no etching. It follows then that the above acids are not sufficiently strong to dissolve this mineral, or else it is not a straight magnetite (Fe_3O_4). A qualitative analysis, however, confirms that it is a pure magnetite, containing no titanium, magnesium, chromium or other elements sometimes found replacing a part of the iron. These results were further confirmed by powdering a crystal of pure Fe_3O_4 and digesting for a short time on the water-bath with acids of various dilutions. It was found that as the strength of the acid was increased the solubility of the magnetite also increased, and when treated with concentrated hydrochloric acid only a few minutes were required to completely dissolve the mineral. While some of the mineral was dissolved, enough

*Loughridge, R. H., Am. Journ. Sci., 1874, (3. S.) 7, 21.

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remained undissolved to show that hydrochloric acid of the usual dilution is quite insufficient to completely dissolve the magnetite.

Attention is further called to the large percentage of alumina extracted by the various acids in the above table. Investigation by others has shown that the amount of this constituent extracted by a quarter normal solution of hydrochloric acid rarely exceeds 4.75 per cent. The explanation in this case would seem to be in the variety of the feldspar since this is the principal source of the alumina in the rock. Both its chemical nature and optical properties place it as a labradorite and belonging therefore to the basic plagioclases, the solubility of which increases as the anorthite molecule is increased.

[European and American Glacial Geology compared. VII.]

FJORDS AND SUBMERGED VALLEYS OF EUROPE.

By Warren Upham, St. Paul, Minn.

Hundreds of fjords, ranging from a few miles to a hundred miles in length, indent the hilly and mountainous plateau of Norway. The seashore of the country, measuring about 1,700 miles in its general outline, is multiplied sixfold by its intricate windings and by these long, narrow, and often branching fjords. Along the outer shore, also, thousands of islands, islets, and skerries of bare rock, have been left during prolonged subaërial erosion, being divided by channels which are the ramifying continuations of the fjords that penetrate the mainland. The greater parts of the steamer routes on all the west coast of Norway, from Stavanger to the North cape, are sheltered from the open sea by island breakwaters which form almost continuously the outer coast line.

Beyond this present coast, the submerged border of the continental plateau reaches to a distance that varies from 10 to 125 miles. It is widest for two degrees next south of the Arctic circle, and narrowest near lat. 69° 20′, off the north end of Andö. The depth of the submerged continental border is 300 to 600 feet along a distance of 200 miles upon the extensive bank which adjoins the mountain range of the Lofoten islands;

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but elsewhere the depth of this margin of a former land surface is from 900 to 1,200 feet. Through all its course the old land border is limited by the submarine contour of 200 fathoms, from which a much steeper descent, precipitously steep west and north of the Lofotens, sinks rapidly to oceanic depths of 3,000 to 9,000 feet.

The shallow, submerged plain, having a mean width of 60 to 75 miles, was doubtless built up as low coast lands, while this part of Europe stood 600 to 1,200 feet higher than now. Its material was supplied from the waste of the higher land through its erosion by rain and streams, sculpturing the elevated peninsular plateau into mountain peaks and ridges, with cañon valleys which have since become the sea-filled fjords. The time of this highland erosion and coastal deposition may have comprised the whole of the Mesozoic and Tertiary eras, which are not represented here by any formations above the sea level. It was separated from the present time, however, as I believe, by a great epeirogenic movement of much higher uplift of northern Europe, preceding the Glacial period and causing its vast snow and ice accumulation, and by an ensuing depression, which in its turn caused the relatively sudden termination of that period by the melting of its ice-sheet.

In my journey a year ago from Helsingborg, Göteborg, and lake Wenern, to Christiania, lake Mjösen, and Trondhjem, and thence east and south to Stockholm and to Göteborg again, only a glimpse of this great peninsula was obtained, which, happily, I am enabled to supplement somewhat fully through the aid of a valuable series of maps and coastal charts kindly supplied me by Dr. Hans Reusch, the director of the Geological Survey of Norway, and through other maps and brochures received from Dr. Andrew M. Hansen, of Christiania, Prof. Otto Torell, director of the Geological Survey of Sweden, and Dr. Edvard Erdmann and Baron Gerard De Geer of the same survey. The Norwegian maps, showing altitudes of the land and depths of the sea, both offshore and in the fjords, have been of especial service in this paper, which will consider the origin of the fjords in its bearing on the probable cause of the Ice age through high continental elevation. For this purpose the following table presents notes of some of these very remarkable valleys in their order from south to north:

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FJORDS OF NORWAY.

	Length. Miles*	Width. Miles.	Maximum depth. Feet.*
Christiania fjord	50	1-8	1,380
Stavanger fjord	30	0.5-5	2,350
Lyse fjord	23	0.3-1.2	1,414
This tributary of the Stavanger fjord is inclosed by precipitous cliffs 2,000 to 3,300 feet high.			
Hardanger fjord, with the Bömmel and Sör fjords	100	0.5-4	2,195
Sogne fjord, with Lyster fjord	112	1-4	4,080
The depth of the Sogne fjord, the longest in Norway, at the mouth of Aurlands fjord, 75 miles from the outer coast, is 3,875 feet; and this southern branch fjord, 16 miles long and about one mile wide, lying between precipitous rock walls 3,000 to 4,000 feet high, has a depth of 1,535 feet at the mouth of its magnificent tributary, the Nærö fjord, which is about ten miles long and varies in width from a tenth to three-fifths of a mile.			
Nord fjord	60	1-2	2,100
Stor fjord, with Geiranger, Sunelvs, and Sule fjord	60	0.5-3	1,495
Molde or Romsdals fjord	35	1-5	1,440
Trondhjem fjord, with Beitstad fjord	90	0.7-8.0	1,895
Ranen fjord, lat. 66 degrees	55	1-3	1,450
Vest fjord, with Ofoten fjord	80	2-20	2,090
Alten fjord, with Stjern sound, to the outer coast line	55	2-10	1,375
Varanger fjord	35	3-12	1,340

It is noteworthy that several of these fjords are of nearly the same depth, from 1,380 to 1,495 feet, which, I think, represents approximately the maximum Pliocene elevation of the country, during the later part of the time of formation of the submerged coastal plain. Numerous channels in that plain, which probably were its Pliocene river valleys carrying the drainage of the central highlands to the coast of that time, sink 100 to 500 feet below the adjoining sea bed. Soundings to the bottom of these submarine valleys range from 500 to 1,420 feet, agreeing well with this estimate of 1,400 or 1,500 feet as the maximum amount of the Late Tertiary elevation. These channels are situated far offshore, with no prominent higher tracts so near as to possibly account for exceptionally

*Distances are given in English statute miles, and depths in English feet. The Norwegian foot equals 1.0294 of English measure.

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powerful glacial erosion along their courses, such as may be supposed to have greatly deepened some of the fjords.

One of the most interesting of the preglacial river valleys now submerged extends thirty miles out in a nearly straight west-northwest course, from the mouth of the Sule fjord, which is the seaward continuation, between islands, of the Stor fjord. This is a well defined channel in the sea bed, having a width of one and a half to two miles. Its depth is mostly 850 to 1,000 feet, with depths of only 200 feet, or less, to 500 feet, on each side. It is called, on the chart, Bredsundsdybet (the "Depth in the Broad sound"). Before reaching the edge of the submarine continental slope, this channel gradually shoals out within five miles and is lost, the depth of the sea there being only about 300 feet. From the central part of its course, however, a wider submarine channel of 500 to 885 feet depth, runs southward and thence westward to the deeper sea, indicating the probable course by which the preglacial valleys of the Nord and Stor fjords discharged their united waters.

Besides the preglacial stream and sea deposits which mainly built up the coastal plain, it is certain that much glacial drift is spread over it, everywhere partially filling the old river courses and probably in many places covering them entirely. The drift deposition appears to have been deepest, however, just along or close outside the present shore, in the meandering channels of the coastal belt of islands, and at the mouths of the fjords, which always attain their greatest depth at some distance inland. Although some of the fjords exceed 2,000 feet in depth, and one is 4,080 feet deep, the mouths of them all are comparatively shallow, being usually from 100 to 300 or 500 feet deep. Whether we ascribe the excavation of the deeper fjords chiefly to preglacial streams or chiefly (in its latest and deepest part) to glacial erosion, we shall in either case be led to the conclusion that their mouths and the adjoining sea must be much built up with glacial deposits.

The British Isles, as shown by the studies of Prof. James Geikie, Prof. Edward Hull, and others, stand on a broad, shallowly submerged continental platform, which is terminated westward, at the submarine contours of 100 to 200 fathoms (600 to 1,200 feet), by steeply descending slopes to the abyssal ocean. Narrow valleys from 100 to 400 feet deep below the con-

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tiguous sea bed, with their bottoms 570 to 1,194 feet below the present sea level, are ascertained by soundings in various parts of the British submarine platform. The most notable of these valleys are the "Hurd Deep," four to five miles across and extending 70 miles westward in the English channel, south of the limits of glaciation, and a remarkable valley extending 30 miles with a width of one and a half to two miles and depth of 300 to 400 feet below the bed of the deep and broad passage that separates Scotland and Ireland. The position and narrowness of the second of these submarine valleys, as of those noted off the coast of Norway, preclude its reference to glacial erosion. Its maximum soundings, 1,194 feet, indicate for this region during some part of the Pliocene period, while the alluvial and marine deposition of the British platform was being completed, an elevation probably 1,200 to 1,500 feet higher than now, or nearly like that estimated for Norway during the same period.

Farther south, where no confusing conditions of glacial erosion and deposition can impart any uncertainty to our interpretation of contours of the submerged continental border, we have in the southeast part of the Bay of Biscay a most significant ancient river valley in the sea bed, traced about 120 miles westward from Cap Breton, France, nearly parallel with the northeast shore of Spain. Coast charts kindly obtained for me in Paris by Prof. N. H. Winchell supply the following notes of this wonderful submerged river course, which is called the "Fosse de Cap Breton." It begins a quarter of a mile offshore about one mile north of Cap Breton village, having there a depth of 125 feet; within the next quarter of a mile it deepens to 230 feet, with a depth of only 50 or 60 feet close north and south; and a mile offshore the old valley has a sounding of 350 feet, but only a depth of 100 feet is found within a fifth of a mile both north and south. Along the next five miles the submarine valley sinks to a depth of 1,000 feet; but it includes one sounding of 1,220 feet at a distance of three miles from the shore. Its width at this exceptionally deep spot is about one mile, the sea bed on each side having the depth of 130 to 150 feet. At the distance of six miles the valley is one and a half miles wide, with soundings of 260 feet to the general continental slope, beneath which the old river

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had cut down about 750 feet. Twenty-five miles from the Cap Breton shore, the valley has the profound depth of 3,670 feet, and has widened to about ten miles between the tops of its sides, which, like the general sea bed of large expanses north and south, have the depth of about 460 feet. At forty miles the valley has a sounding of 6,135 feet. At eighty miles its depth is 7,140 feet. Within seven miles farther it more rapidly deepens to 8,700 feet, with 650 and 1,175 feet less depth two miles away respectively on its south and north sides. Thence along a distance of thirty miles it holds a somewhat uniform depth from 8,700 to 9,000 feet, this being apparently the measure of the maximum continental uplift when the old river eroded its valley. Thirty miles northward from where the valley ceases to be recognizable, the Bay of Biscay is 10,830 feet deep, and twenty miles farther north its depth is 12,600 feet.

The present representative of the old river is the Adour, which has its mouth ten miles south of the "Fosse de Cap Breton;" but formerly it was turned northward by dunes, so that its mouth at the end of the fourteenth century is said to have been about ten miles north of Cap Breton.

This submerged Adour valley is the most accurately known, by special hydrographic surveys, among several others on the border of the continental plateau in the Bay of Biscay and along the western coast of Spain and Portugal, which together demonstrate for southwestern Europe an uplift of late geological date to a vertical amount ranging probably from 5,000 to 9,000 feet. The border of the continent, built out by sedimentation during the Tertiary era to the submarine contours of 600 to 1,200 feet, with steep descent thence into the deep ocean, has mainly on these coasts a width of 10 to 30 or 40 miles. Subsequent to the formation of this continental shelf bordering the hilly and mountainous present land area, western Europe and western Africa experienced an epeirogenic uplift which at its maximum, as known by the submerged Adour and Congo valleys, lifted these great land areas from one mile to nearly two miles vertically above their present altitude.*

*From the mouth of the river Congo its submerged valley is traced by J. Y. Buchanan to a distance of about 100 miles and a depth exceeding 6,000 feet; and another submarine valley of great depth, called

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Inquiring by what means the fjords of Norway received their excavations to depths that now are 2,000 to 4,000 feet beneath the sea level, I believe that its explanation is found chiefly in river erosion permitted by epeirogenic movements. The early Pleistocene uplift of western Africa and the Spanish peninsula probably extended to the British Isles and Scandinavia, giving in these northern latitudes snowfall through all the year, by which the European ice-sheet was amassed. During the progress of the uplift, to its culmination in the Ice age, perhaps 100,000 years elapsed, affording sufficient time for the rivers to cut the submarine valleys and the deep fjords. For a long period northern Europe was enveloped by snow and ice, which attained great thickness and weight, averaging probably a half mile in depth on an area of about 2,000,000 square miles. Under its weight the land sank to a maximum in the Scandinavian peninsula of about 1,000 feet, as determined by Baron De Geer, below its present hight; and the ice sheet, with the restoration of low altitude and temperate climate on its border, was rapidly melted away, the unburdened land meanwhile rising from its subsidence. The epeirogenic deformation was doubtless greatest along the continental borders, and it may have permitted the Scandinavian high plateau to rise and sink and again rise, while the continental margin now beneath the sea underwent only a small part of the amount of oscillation that the fjords indicate for the interior of the country.

It seems needful further to add only a few words that attention may be directed also to the well known studies by Lindenkohl, Spencer, and others, of hydrographic surveys on the Atlantic coast of Canada and the United States and in the West Indies, and of Davidson on the Pacific coast of the United States and of Lower California, which show for North America an early Pleistocene uplift of similar altitude as on the east side of the Atlantic in the Old World. The fjords

the "Bottomless Pit," is found by soundings near lat. 5° N. on the African coast (Scottish Geog. Mag., III, 217-238, with charts and submarine profiles, May, 1887; Proc. A. A. A. S., XLI (1892), 171-173). The submerged valleys of the French, Spanish, and Portuguese coasts have been recently studied by Prof. Edward Hull, who writes that "the great uplift, presumably reaching its maximum at the commencement of the Glacial epoch, is conclusive" (Nature, LVII, 582, April 21, 1898; LVIII, 51, May 19, 1898).

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of the glaciated northern part of our continent, of the Arctic archipelago, and of Greenland, having a maximum depth of more than 3,000 feet in the Franz Josef fjord of eastern Greenland, agree with the Norwegian fjords in pointing to epeirogenic causes of the Ice age and of its sudden end.

REMARKS ON THE CLASSIFICATION OF THE MISSISSIPPIAN SERIES.

By CHARLES R. KEYES, Des Moines, Iowa.

When, a few months ago, occasion was taken in this journal to give some of the reasons why the name Augusta, as a title for one of the subdivisions of the Mississippian series, had been used in the reports of the Iowa and the Missouri geological surveys, it was not anticipated that the subject would have to be again referred to so soon. However, Mr. Weller, in recent issues of both this magazine and the Journal of Geology, takes exception to the facts presented. He would have us believe that grievous errors had been made in adopting any other title than Osage, and in not following the classification of the Mississippian rocks proposed by his former instructor in geology. It is unnecessary to reiterate the facts already given.* It does, however, seem desirable to call attention briefly to some other phases of the subject, that should have been, perhaps, included in the former article. Significantly enough Mr. Weller makes not the slightest allusion to them.

As to whether Augusta or Osage should be the title retained for one of the members of the Mississippian series is a matter of small consequence. One name is as good as another for a formation, provided it has some significance and it accords with the laws of usage in the science in which it occurs. So far as the two names mentioned are concerned Osage is, I think, much the prettier. Under ordinary circumstances it would be, according to my own ideas, preferable. It is, indeed unfortunate that there should exist conditions in science compelling us to become familiar with names for which we have no liking.

In his last paper, arguing for the adoption of Osage in place of Augusta, Mr. Weller, as a lawyer, has no doubt entered the

*This journal, vol. XXI, p. 228, 1898.

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very best plea possible for a lame case. Were this feature not so conspicuous throughout his presentation one would be almost forced to the conclusion that our critic had not read very carefully the literature of the subject. For example, in the leading quotation that he makes he could have easily quoted one clause farther, giving to my sentence a meaning directly opposite to the one that, as it now stands, must be inferred.

Now, as a matter of fact, Mr. Weller has avoided entirely the vital factors determining the choice of one of the two terms under consideration. When the "impartial judges" come to examine the literature (if they ever do) they will certainly have to search his last remarks long and vainly for a single point wherein he has touched upon the essential features of the paper he criticizes. One cannot help thinking that if the author of "Osage vs. Augusta" had devoted but one tenth of the time in examining the other side of the question, that he has manifestly done in viewing it from his own standpoint he would have come to very different conclusions.

When "Use of the Term Augusta in Geology" was considered only a few of the stratigraphical and paleontological reasons for not using Osage were presented. The name Osage, as it appears in geological literature, also has a nominal history. It has been applied repeatedly to geological formations long before it was thought of in connection with the Burlington and Keokuk limestones. The name is widely known in both Missouri and Kansas, referring to certain coals and their accompanying shales, in fact to several distinct sets of beds in both the Des Moines and Missourian series. One of these will doubtless stand as a useful geological term. Moreover, the formations to which Saunders and also Hay have given the name in question have been, I believe, as well defined as most of the other geological formations now recognized in the region. King, Owen and Johnson have also used the name Osage in no uncertain sense in the same region; and it is not improbable that one of these meanings will have to be retained, if we consider at all the law of priority, and desire to do justice to workers no less conscientious and scientific in their day than we find in ours.

Personally I care nothing whatever about the title Augus-

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ta, merely because of the fact that I happened to suggest it. I have always found it the best to use terms already in use if it is possible to do so. When an author proposes, defines and publishes a name in science it ceases to be his property and subject to his control. He cannot withdraw it or replace it. His insistence upon its adoption avails nothing. The workers in his branch determine its usefulness or its uselessness in accordance with the laws of nomenclature that best subserve the science. Judgment passed upon titles must have as its foundation the avoidance of confusion. Were it possible, I would be perfectly satisfied to substitute for Augusta the name Dewey, Hobson, or even Yankee Doodle, if those who are to come in contact with the formation would propose it and agree to its usage.

In view of the fact that the name Osage is almost certainly to be retained for another member, having the same taxonomic rank, of the Carboniferous in the same region, and in view of the many other objections regarding the character of the subdivision it is proposed to refer to, as enumerated in a previous article, I am not yet convinced of the advisability, or of the desirability of using the name for any part of the Mississippian series.

Mr. Weller is a paleontologist. He is well acquainted with the code of rules governing the nomenclature of fossils. He knows full well that essentially the same rules exist in other branches of science. Why then should he expect to enter the field of geology and not expect to follow the same laws, at least in spirit, as nearly as possible.

In his other article on the Mississippian series, Mr. Weller dwells upon the "higher purposes of major classifications as an expression of the vital features of the history of the region," whatever that may be. He speaks also of the applicability, in a geologic province, of an epoch name "as a stratigraphic name to all strata deposited during that epoch." In the very next sentence he says: "It may not always be possible to draw a sharp and fixed line in the stratigraphic series between two succeeding epochs so that every where throughout the geologic province the exact limits of the historical epochs may be pointed out."

There never was a clearer presentation of the utter incon-

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gruity between an hypothesis of geological correlation and classification and the practical scheme as actually developed in the field. Has it not been this very lack of effort to draw close lines that has enabled the paleontologist to fancifully extend the geological formations around the world, like the concentric layers of an onion? Is it not this very discordance between the theoretical fossil scheme and the actual succession of beds as determined by exact methods that has led every working geologist in this country to abandon the fossils as the all-important criterion, and to use in their place for the stages and series the lithological and other characters? Until this theoretical fetish was set aside stratigraphy and historical geology, as usually limited, had not made a single step forward for 50 years.

The subdivisions of the Mississippian series form one of the best examples that could possibly be selected to illustrate the point. Mr. Weller says that the arrangement proposed "by Williams is a natural faunal classification, while the second by Keyes is a stratigraphic classification." Just what an unnatural faunal one is we are left to conjecture. The subdivisions of Chouteau, Osage and Ste. Genevieve remain to this day wholly undefined, except in terms of the stratigraphy. There exists not even the slightest trace of a criterion by which to distinguish a Chouteau from a Ste. Genevieve fauna, or an Osage fauna from an Osage indian. Yet, says Mr. Weller, "the commonly recognized local geological formations were placed as accurately as was possible at that time, in their respective epochs, and further investigation seems to necessitate no different disposition of them." Of course not! How could they be differently disposed in a scheme having no definition and hence no existence.

Only two persons exist who understand what makes up each of the three faunas of the Mississippian series. One is the author of the names himself and the other is his defender. If, however, judging from the defense, the Chouteau or Kinderhood fauna is a "natural faunal unit," if the Ste. Genevieve fauna is a natural and homogenous group" it is to be hoped that in our final faunal classification of geological time and substance, we shall have only unnatural faunal groups to work upon.

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But to get back to some of the more essential facts of the matter: The two classifications are not based upon wholly different data, as might be inferred from the recent articles. The one scheme purports to be based entirely upon the infallible fossils; the other on the combined testimony of the paleontology, the stratigraphy, the lithology and general physical records of the province. The one considers historical geology in the narrower sense commonly given in the text-books; the other in the broader geological sense. The two do not differ very much in practical application; and not so much but that they may be readily adjusted.

If professor Williams has indeed proposed names that he has not yet defined it is no reflection on the essential features of his classification. It often happens that geological terms get into literature before it is understood perfectly just what they are intended to express. In the cases of the three names under consideration it has been known for several years that professor Williams has been at work on a monograph of the Mississippian faunas, in which the three distinctions will be clearly set forth.

It may be concluded therefore, that the names Chouteau, Osage and Ste. Genevieve have not been used more widely for one reason before all others. Previous to their application as an episode or age title they had been clearly defined and extensively adopted in other senses. Chouteau limestone had already been used by Swallow for one of the formations of the Mississippian series. It was clearly defined; and it is still a common and useful term. Osage has been already commented upon. Ste. Genevieve was one of Shumard's names for a distinct formation; and by him was well defined. It is bad practice to use such names in very different senses. It is confusing, to say the least, to perpetuate synonyms even though they are pet names.

Recent faunal investigations seem to indicate the base of the Mississippian series to be the bottom of Swallow's Chouteau limestone. In this case, when a time name is to be recognized, Chouteau by modification becomes available. Yet, curiously enough, Mr. Weller, in his late article discards this term—the only one of the three that could possibly stand under the laws of priority.

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Stripped of all their unessentials it appears that the two classifications of the Mississipian series, if they may be called two, are to all intents and purposes the same, so far as their practical workings are concerned. The fact that the terms proposed by professor Williams are not used is not on account of any lack of appreciation of his work. It is because the names are clearly preoccupied to begin with, and because of the difficulties already mentioned. In this and all similar cases it is the duty of the active workers to try to get together and not to attempt to unnecessarily widen unimportant differences, which can readily be harmonized.

EDITORIAL COMMENT.

The question of the differentiation of Magmas.

Of the recent publications relating to the origin of the variations of the igneous rocks of the earth, those of Rosenbusch, Brögger and Iddings being among the earliest, the recent brochure of Michel Levy* is one of the most trenchant. The author gives a short review of the work of the last ten years as expressed in the articles published by Teall, Rosenbusch, Brögger, Lang, Iddings, Becker.

Teall, adopting and applying the principle of Soret of a solution of basic silicates in silicates more acid, explained the more basic borders of certain laccolytes by the concentration of the former class of silicates in the cooler portions of the molten mass, hence on the borders of the laccolyte. But, (as remarked by the author), unfortunately Fouqué had already shown (1879) facts diametrically opposite in the dikes of Santorin, where the borders are more acid than the centre.

Rosenbusch's idea of "kerns" or segmentations of the primordial magma (1889), is only a further application of Teall's hypothesis, supposed to take place at greater depths. Of these separations, Rosenbusch recognized six primitive

*Classification des magmas des roches eruptives. Par. A. Michel-Levy. (Extrait du Bulletin Soc. Geol. de France. 3 me. ser. XXV., 326, 1897).

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magmas, distinguished by the relative chemical proportions existing between the alkalies, lime, magnesia, alumina, iron and silica. Of this the author remarks that, "except the foyalitic and the peridotic magmas, the others are arbitrarily defined and are in reality only an embarrassment in the study of rocks very dissimilar. The theoretical examination into the 'kerns' of Rosenbusch, distinguished by stoechiometric proportions, leads at once to a mineralogical determination, but it reveals then one important lack, viz., the black and white micas; the excess or the absence of alumina has not been sufficiently taken into consideration, and the history of acid and intermediate magmas is singularly obscure."

As to the "differentiation" of magmas, put forth (1892) by Iddings, under the idea that the fundamental magma undergoes sundry changes at volcanic centres producing a succession of different rocks in a certain order, the author discredits, first, the assumption that such a fundamental magma exists, and second he considers that the facts of observation do not warrant such segmentations as have been predicated by Iddings. However, the author considers the "capital memoir" of Iddings on the origin of eruptive rocks the most instructive and the most suggestive. Iddings' criticisms of the views of his predecessors are more convincing than his own conclusions.

The cause of such differentiations, if they exist, Iddings supposes to consist principally in differences of temperature, the extremely variable dissolvant, changing with the nature of the magma, is influenced by the conductibility of the walls of the subterranean chambers which it fills. Pressure is quite subordinate to heat. This is essentially the idea of Soret,—it is the theory of a closed chamber (vase clos). In this process of differentiation, as set forth by Iddings in his abscissas and ordinates, the relative proportion of the alkalies, potash and soda, bears the most important rôle, being the least variable in each family. The first rock to appear in a family of common consanguinity, according to Iddings, is an intermediate one, the later rocks being variations in opposite directions toward extremes of acidity and basicity. This intermediate rock may be the result of differentiation from a primitive magma, which thus repeats essentially the segmen-

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tation theory of "kerns" of Rosenbusch against which Iddings himself brings the strongest arguments.

Brögger's work began in 1890 and has been but lately concluded. He believes the principle of Soret explains the concentration of the basic silicates on the borders of laccolytes, and, consequently the order of appearance of intrusive magmas—first the basic and then the more and more acid. In that he agrees with Teall. In order to obtain an approximation to the nature of the fundamental magma Brögger took the average of all the intrusive rocks of the region of Christiania, but, according to the author, the extreme richness in soda of all the rocks having the "air of family" of the region of Christiania, precludes the possibility of accepting Brögger's result as an indication of the nature of the fundamental magma.

Lang (1891) classed the magmas of eruptive rocks into four grand divisions according to the relative total quantities of lime, soda and potash which they contain, viz:

1. Rocks in which potash predominates over the sum of soda and lime.
2. Rocks in which soda predominates over potash and lime.
3. Rocks in which the alkalies predominate over lime.
4. Rocks in which lime predominates over the alkalies.

The author remarks that in such a classification, lime acts a double rôle, from a mineralogical point of view—that is, whether it is associated with the ferromagnesian minerals or with the silicates of the alkalies; and further, Lang took no account of magnesia which as it appears plays a capital rôle in the natural grouping of magmas.

The four classes of Lang, based on the relative prevalence of the alkaline elements, are in a measure comparable with the five principal kerns of Rosenbusch, but in details of application they vary widely.

Becker has considered six primitive magmas differing from each other by their relative contents of calcium, sodium and potassium, and has devised an elegant geometric method of representing them graphically, according to their analysis en bloc. This method is comparable with that of crystallography, in which co-ordinates, h k l, are variable units, and are

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laid off on vertical and horizontal axes according to their value. Here the relative values of Ca, Na, and K serve the same purpose. He considers two magmas in which potash is in excess, and also two each for an excess of lime and soda. The elements silica, alumina, magnesia and iron are represented by the vertical lines by which their values are expressed.

The author prefers a different scheme of representing the comparative analysis of massive rock. This scheme and its application to a large number of analyses comprise the chief part of this work.

In the first place he recognizes but two eruptive magmas having sufficient individuality to enter into a fundamental discussion. All others he considers arbitrary, accidental or fanciful. These two are:

(1) That which is destitute of ferromagnesian elements and which Rosenbusch has divided into two parts, viz: foyalitic and granitic. It is essentially an alkaline magma, from a chemical point of view, and contains no magnesia.

(2) That which is almost exclusively composed of ferromagnesian elements, comprising lamprophyres and peridotytes, corresponding to the peridotic type of Rosenbusch and to a part of that of his gabbros. Chemically this contains a larger amount of magnesia than of lime.

Thus magnesia is taken as the point of departure in his classification. It represents, with the greatest fidelity, the relative quantity of the ferromagnesian magma. Iron is more or less irregularly introduced, lime plays a double rôle, being partly involved in the feldspars and partly incorporated in the bisilicates or mono-silicates. Magnesia is always characteristic of the ferromagnesian elements, bisilicates, monosilicates, black micas, etc., and is present in inverse proportion to silica.

Secondly the author considers the relation existing between the alkalies (potash and soda) as the only characteristic and reliable trait on which to base the division into families. This is deducible from the study of Mr. Iddings of rocks of increasing acidity (which increases as the magnesia diminishes) in which it is seen that everything else in liable to irregular variation. It is an error to complicate the relation of the alkalies by a comparison with the total lime, which tends toward zero with the ferromagnesian elements.

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In the next place he separates the content of lime into two categories, viz: that concerned in the formation of the feldspars, and that which enters into the ferromagnesian bisilicates. This separation, however, is intimately associated with the disposition of the alumina present, which goes first to saturate the alkalies, the remainder entering into the hornblendes, micas, etc.

Thus, the chemical elements, and the composing minerals of all crystalline rocks coming from magmas, are separable between the two types, the alkaline-earthly type and the ferromagnesian type. The dominant characters in each are given leading rôles in his scheme of graphic representation. In the first he constructs a triangle of potash, soda and lime, giving each element a position, according to its amount, on perpendicular ordinates and abscissas, coloring it blue in his plates. The ferromagnesian triangle is composed in a similar manner by arbitrarily assigning the leading elements in the ferromagnesian group to positive or negative positions on the same axes. This triangle is distinguished by being lined in black. The exceptional combinations and occasional excesses of any of the elements are adjusted among themselves by certain convenient compensations or by special representations. The triangles thus constituted, placed in juxtaposition, afford a fundamental graphic presentation of the composition of similar or of contrasting rocks. The proportion of silica contained in a rock does not figure in this classification.

The alkaline elements of the magma as represented, include soda, potash and so much of the lime as is required by the feldspars. Any excess of soda, as in the soda-bearing bisilicates, is specially expressed.

The ferromagnesian portion of the magma has a triangle which expresses the proportion of magnesia, iron and the lime which remains after the formation of the feldspars. If there be no lime remaining this triangle is reduced to a vertical line. Also, in case of an excess of alumina above that required for the feldspars, this is assigned to the ferromagnesian triangle and may take the place of a lack of lime in restoring the triangle.

Nearly all grouped chemical analyses hitherto published of igneous rocks that have been considered allied in origin, such

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as those of Iddings, Lang, Zirkel, Rosenbusch, Weed and Pierson, Washington, Lasaulx, Fouqué, Rust, Becke, Duparc, Ritter, Termier and Brögger, are represented by such triangles in a series of plates, and on the same plates are represented the triangles of the leading minerals of these rocks.

The ferromagnesian triangle is found to be divisible, first into four parts, or positions, according to the relative proportions of magnesia and lime included in feldspars, viz: magnesia zero; magnesia less than the lime; magnesia equal to the lime, and magnesia greater than the lime; and each of these is further separable into three subdivisions depending on the presence or excess of alumina, lime or of soda.

The alkaline-earthy triangle is also divided into four parts, based on the amount of lime present in the feldspars, and each part is again divided into four more according to the potash it may contain.

Each analysis, therefore, is represented by two triangles placed in juxtaposition upon the chosen abscissas and ordinates, and being differently colored give a striking expression of the composition of the rock concerned. The scale of the diagrams is two millimetres for one per cent., drawn on ordiary engineer's paper lined in squares of one millimetre.

In a general table all rocks, expressed by such triangles, are also grouped in vertical and horizontal columns, the vertical columns expréssing the alkaline or alkaline-earthy constituents and the horizontal the ferromagnesian, with the same distinctions as employed in the construction of the triangles.

This classification is intended as a fundamental framework for the comparative grouping of crystalline magmas. It ignores all such accidental elements as structure, age, texture, and even the mineralogical composition, and embraces only the quantitative chemical composition. It serves as a point of departure for the investigation of the question of the origin of the various igneous rocks and the cause of their variation and succession, a line of inquiry which the author does not fully enter upon in this paper—only outlining in a series of critical conclusions the methods necessary to follow in such an inquiry.

As an illustration he applies this chemical classification to a series of igneous rocks recently studied by Weed and

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Pierson*, viz: the rocks of the "Castle Mountain Mining District" in Montana, which present, in a high degree, the stamp of "consanguinity." After the discussion of this series of rocks, which is further illustrated by a series of triangular diagrams constructed according to the foregoing principles, he remarks that "this all appears as if, to a pure ferromagnesian magma but slightly variable, had been added, in succession, variable amounts of the alkalies, at first rapidly increasing, of alumina and silica; then, after the point of saturation of the potash, soda and alumina, silica alone continues to increase and to take the place even of the ferromagnesian magma.

The diagram of Iddings, put under the author's form of expression by contrasting triangles, also shows perfectly the diverse types of magmas formed successively by such mixtures.

In conclusion the author calls attention to sundry theoretical considerations bearing upon the variation of magmas, and discusses briefly certain hypotheses, viz:

1. There are but two magmas that are susceptible of precise definition—the ferromagnesian and the alkaline. These have a constant individuality. But it is to be admitted that neither of these contains their elements in fixed, or even in stoechiometric proportions, but are quite variable, especially the alkaline magma in which the per cent of silica can vary from 51 to 100. The mutual independence of these two fundamental magmas is confirmed by a study of a natural series according to the method of Iddings. They do not act in the same manner in their evolution from their eruptive source. In general the alkaline magma remains stable while the ferromagnesian is replaced in whole or in part, by pure silica. There is, therefore, a profound contrast between these magmas. The ferromagnesian seems to play the rôle of an igneous scoria, while the alkaline, being capable of insideous injection, seems to be carried, by means of dissolvents and mineralizing agents, and disseminated sometimes after the fashion of liquid solution or even of volatile gases.

2. A natural method of differentiation of magmas ought to fill certain conditions. These conditions must be found in the deep-seated reservoirs at the points of union of

*Bulletin 139 U. S. Geol. Survey, 1896.

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varied portions of these two magmas. The supposed mode of differentiation must explain not only the birth of a series of rocks of the same family, but also the origin, at great distances, of certain series, and on the contrary, also the possibility of remarkable differences between two neighboring centers. It must, further take account of igneous rocks found at great depths and of those that solidify at the surface of the earth. With the former it touches the problem of contact metamorphism, and that of the striking resemblance of the crystalline schists to the massive granitoid rocks, and of their apparently simultaneous production in certain deep-seated zones of the earth's crust. This borders on the question of exomorphous (regional?) metamorphism. Along with endomorphous metamorphism is found the phenomenon of the absorption, by certain granitoid rocks, of large amounts of their surrounding rock walls and the radical transformation of their magmas by such local absorption.

In connection with the classification of rocks found at the surface the problem of vulcanism is involved. Indeed the study of solid magmas spread out on the surface cannot be separated from that of volatile emmanations, which are of a formidable volume and of a weight comparable with that of the fused products. These fumaroles, these clouds of vapor of water, of chlorides, of sulphides, of different carburetted exhalations, continue long after the cessation of the local paroxysms. They testify at least to the connection of metalliferous veins and concretions with volcanic eruptions.

Therefore, exomorphous (or concact) metamorphism leading to the production of the crystalline schists at the expense of beds incontestably stratified; the probable existence of deep-seated zones where general metamorphism gives birth simultaneously to the schists and gneisses and to the granitoid masses; endomorphous metamorphism modifying profoundly from place to place these granitoid masses by partial solution and incorporation of the surrounding rock; extended transference of certain elements by fumarole action—such are the facts which a theory of the differentiation of eruptive magmas must necessarily take account of, without losing sight of the different modes of action of the two different fundamental magmas.

3. These facts scarcely appear to be susceptible of being

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put into accord with the theory of a closed reservoir (vase clos), such as required by the application of the principle of Soret:—that is to say of variations of temperature, in a solution more or less saturated. Here the dissolvent would necessarily be a portion of the alkaline magma, the elements dissolved and susceptible of diffusion, of course, would be the ferro-magnesian magma and silica, one replacing the other. Such is observably the method of segregation, of differentiation, in a well arranged "family." But, as already remarked, this method will never reach the creation of two distinct families having very different proportions of the alkalies, such as Etna and Vesuvius.

4. Local modification of granitic magmas by endomorphous metamorphism explains why certain volcanic series do not present the air of family, or consanguinity required by the theory of a universal magma separated by successive segmentations or kerns. In general, further, it is necessary to admit that in the geosynclinals where accumulate the thickest deposits, at the foot of the mountain ranges of the earth, the isotherms should undergo a rise toward the surface, such as would permit the fusion more or less aqueous not only of magmas already consolidated but even of clastic strata thus brought into the region of the central heat. Now it is precisely in these places of greatest accumulation of sedimentary formations that successive foldings will be produced, such as to permit the ascension and intrusion of granitoid rocks. and later the subsidence of extensive basins like the Mediterranean or the Pacific about the borders of which are located lines of volcanic rocks. The formation of such magmas again, can scarcely correspond to the uniformity which is demanded by the theory of "closed reservoir," and of segregations and differentiation of magmas already differentiated.

5. But the greatest error in the theory of successive differentiation consists in not taking any account of the circulation of volatile agents, and of the ceaseless movement which they must impress on those elements which are susceptible of being carried by them. Geologists are just beginning to believe in the modifying power of surface water, simply charged with oxygen, carbonic acid, or with traces of the chlorides and fluorides. There is no doubt that they cause the develop-

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ment of balls and sponges of silica, the microscopic crystals of orthoclase and of albite in the stratified rocks. (Lory, Cayeux); they give rise to various forms of silica at the outcrops of the Gypse (Munier-Chalmas), they calcify or decalcify (Termier) the basic rocks and they dealkalinize the acid; they produce important rearrangements (de Launay) in metalliferous deposits. At a distance from granite contacts black mica is much developed, also various silicates of alumina, and nearer the contact alkaline feldspars are formed. Lacroix has shown that in the massive lherzolytes of the Pyrenees, which are entirely destitute of alkalies, the micas are developed, also alkaline feldspars and tourmaline, all minerals of the alkaline magma. Here the action of transfer by fumaroles is undeniable. De Lapparent has dwelt on the importance of solfatrine action accompanying modern acid eruptives; and it is known that certain dykes of granulyte and of pegmatyte act like concretionary veins. This fact was early known and is confirmed by numerous observers. The Stockwerks of Zinnwald and of Altenberg furnished many examples of this to our predecessors.

The author, finally, presents a brief exposé of the hypothesis which he proposes for the forms and variations of igneous rocks. The active agent of these alterations is believed by him to be the circulation of fluids under pressure and at a high temperature through the reservoirs containing the eruptive magma. These reservoirs are filled (1) with the ferro-magnesian magma which serves everywhere as a scoria for the impure covering or iron button of the internal mass of the globe, the interior mass being considered essentially irony; (2) the rock-products of this button, such as the alkalies, alumina, silica, which are removable by mineral agents: (3) the result of a refusion of the lower parts of the crust by the rising of the isogeotherms, whether such rising be due to an increase of thinness of the crust or to an ascent of large masses of the fused magma. These circulating fluids combine, under conditions favorable for the operation of the law of Soret, to produce differentiations, the alkaline substances always rising and the ferro-magnesians tending to descend. Hence the first to appear, in case of volcanic action, is the al-

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kaline-magma and the era of activity is terminated by basic products.

Note.—In the foregoing the writer has aimed to give only the views of the author. It may be added that the method of differentiation adopted by the author varies but little from the "crenitic" hypothesis of Hunt, differing principally in the "locus" of the operation. The author supposes the changes to transpire in deepseated reservoirs, and Hunt at or near the surface of the earth. N. H. W.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

The Physical Geography of New Jersey. By ROLLIN D. SALISBURY. With *Appendix*, by CORNELIUS CLARKSON VERMEULE. (Vol. IV of the Final Report of JOHN C. SMOCK, State Geologist.) Pages xvi, 170, 200; with a relief map, 24 plates (maps, profiles, and views from photographs), and 37 figures in the text: Trenton, N. J., 1898.

The first division of this report, in 170 pages, by Prof. Salisbury, treats of the topographic features of the state, and reviews their geologic origin from the close of the Triassic period to the present time, including alternate uplifts and depressions, with their attendant cycles of erosion and deposition. The earliest evidences of glaciation, during the Pensauken epoch, long preceded the deposition of the chief terminal moraine and of the principal mass of glacial drift. The second division, an appendix of 200 pages, comprises valuable reference tables and notes, compiled by Mr. Vermeule, pertaining to physical geography, county areas, population, and magnetic declination. W. U.

Northward over the "Great Ice:" a Narrative of Life and Work along the Shores and upon the Interior Ice-cap of northern Greenland in 1886 and 1891-97; with a description of the little tribe of Smith Sound Eskimos, the most northerly human beings of the world, and an account of the discovery and bringing home of the "Saviksue," or great Cape York Meteorites. By ROBERT E. PEARY. With maps, diagrams, and about 800 illustrations. Two volumes: I. Pages lxxx, 521. II. Pages xiv, 625. New York: Frederick A. Stokes Co., 1898.

The comprehensive title page of this most admirable work indicates quite fully its contents, which include extensive observations of high geologic, meterologic, and ethnographic value. The story of courageous accomplishment of well laid plans of exploration on the ice-sheet and northern shores of Greenland, surmounting many difficulties and intense hardships, is very unostentatiously related. The illustrations

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include portraits of the members and patrons of the several expeditions led by the author, portraits of many of the Smith Sound Eskimos, who numbered 234 a year ago, and many views of scenery, of Eskimo dogs, and of sledging on the ice-sheet.

In May, 1894, as Peary narrates, he was guided by an Eskimo to three large masses of meteoric iron, about 35 miles east of Cape York, which doubtless originally formed a single meteorite, far larger than any other known. The situation of these masses in their relation to the underlying soil and rock implies that the fall took place on a snow-field, perhaps on the surface of the ice-sheet when formerly more extended; and it is clearly impossible that these iron masses are of terrestrial origin like the iron occurring in basalt and in masses weathered from it at Ovifak, 500 miles farther south on Disco island, which in a different way are equally remarkable and unparalleled in any other part of the world. All three of the meteoric masses have been brought to the United States by Peary, two expeditions, the first unsuccessful, being made for the largest, which is estimated to weigh 90 or 100 tons. The other two masses weigh about 6,000 and 1,000 pounds. According to an Eskimo legend, they were a tent, woman, and dog, hurled from the sky. W. U.

Note sur les gisements d'or du Mexique; par EZEQUIEL ORDONEZ. (Bul. de la Sociedad Antonio Alzate, Tome XI, pp. 217-240, 1898).

Within recent years there has been rapid increase in the production of gold in Mexico. This is due not only to the discoveries that have been made of gold-bearing regions, but also to the improved methods of the treatment of the ores, not least among which is the great care that is given to the refining of silver. Many American agents and experts have visited Mexico, and much American capital has sent its representatives throughout the republic; resulting in the organization of powerful companies for exploiting the ores. The richest regions are in the northwestern part of Mexico. Lower California and Sonora hold the first rank. Then follow Sinaloa, Durango, Jalisco, Mexico and Oaxaca. Exportation has risen from 439 kilos in 1886-87, to 10930 in 1896-97. Placers are most frequent on the Pacific slopes of the Sierra Madre mountains. N. H. W.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Ashley, G. H.

Note on fault structure in Indiana. (Ind. Acad. Sci., Proc. for 1897, pp. 244-250, pls. 1-2.)

*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

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Ashley, G. H. (Blatchley, W. S. and)

Geological scale of Indiana. (22nd Ann. Rept. Dept. Geol. and Nat. Resources of Indiana, pp. 17-23, pl. 2, 1898.)

Bagg, R. M.

Report upon the foraminiferal deposits near Bujio, and of the Empire limestone. [In R. T. Hill's paper on the isthmus of Panama.] (Bull. Mus. Comp. Zool., vol. 28, Geol. ser. vol. 3, no. 5, p. 275, June 1898.)

Bell, Robert.

On the occurrence of mammoth and mastodon remains around Hudson bay. (Geol. Soc. Amer., Bull., vol. 9, pp. 369-390, June 22, 1898.)

Blatchley, W. S., and Ashley, G. H.

Geological scale of Indiana. (22nd Ann. Rept. Dept. Geol. and Nat. Resources of Indiana, pp. 17-23, pl. 2, 1898.)

Blatchley, W. S.

The geology of Lake and Porter counties, Indiana. (22nd Ann. Rept. Dept. Geol. and Nat. Resources of Indiana, pp. 25-104, pls. 3-8, 1 map, 1898.)

Blatchley, W. S.

The clays and clay industries of northwestern Indiana. (22nd Ann. Rept. Dept. Geol. and Nat. Resources of Indiana, pp. 105-153, pls. 9-11, 1898.)

Blatchley, W. S.

The petroleum industry in Indiana in 1897. (22nd Ann. Rept. Dept. Geol. and Nat. Resources of Indiana, pp. 155-184, pls. 12-14, 1898.)

Coleman, A. P.

Fourth report on the West Ontario gold region. (Rept. Bureau of Mines of Ontario, vol. 7, pt. 2, pp. 109-145, 1898.)

Coleman, A. P.

Notes on the petrology of Ontario. (Rept. Bureau of Mines of Ontario, vol. 7, pt. 2, pp. 145-150, 1898.)

Coleman, A. P.

Clastic Huronian rocks of western Ontario. (Rept. Bureau of Mines of Ontario, vol. 7, pt. 2, pp. 151-160, 1898.)

Crawford, J.

Recent severe seismic disturbances in Nicaragua. (Am. Geol., vol. 22, pp. 56-58, July 1898.)

Cummings, E. R. (Prosser, C. S. and)

Sections and thickness of Lower Silurian formations on West Canada creek and in the Mohawk valley. (15th Ann. Rept. State Geologist of New York, pp. 615-659, pls, 1-12.)

Dall, W. H.

Report upon the paleontology of the collections. [In R. T. Hill's paper on the isthmus of Panama.] (Bull. Mus. Comp. Zool., vol. 28, Geol. ser. vol. 3, no. 5, pp. 271-275, June 1898.)

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[Dana, J. D.]

James Dwight Dana. By Prof. James Geikie. (Proc. Royal Soc. Edinburgh, vol 21, obituary notices, pp. x-xvi, 1897.)

Daniells, W. W.

On the analysis of the water of a flowing artesian well at Marinette, Wisconsin. (Trans. Wisconsin Acad. Sci. Arts and Letters, vol. 11, pp. 112-113, 1898.)

Eakle, A. S.

Erionite, a new zeolite. (Am. Jour. Sci., ser. 4, vol. 6, pp. 66-68, July 1898.)

Elftman, A. H.

The St. Croix river valley. (Am. Geol., vol. 22, pp. 58-61, July 1898.)

Foerste, A. F.

A report on the Niagara limestone quarries of Decatur, Franklin and Fayette counties, with remarks on the geology of the Middle and Upper Silurian rocks of these and neighboring (Ripley. Jennings, Bartholomew and Shelby) counties. (22nd Ann. Rept. Dept. Geol. and Nat. Resources of Indiana, pp. 195-255, pls. 14-18, 1898.)

Fuller, M. L.

Notes on a Carboniferous boulder train in eastern Massachusetts. (Proc. Boston Soc. Nat. Hist., vol. 28, no. 9, pp. 251-264, June 1898.)

Geikie, James.

James Dwight Dana. (Proc. Royal Soc. Edinburgh, vol. 21, obituary notices, pp. x-xvi, 1897.)

Herrick, C. L.

The geology of the environs of Albuquerque, New Mexico. (Am. Geol., vol. 22, pp. 26-43, pl. 6, July 1898.)

Hill, R. T.

The geological history of the isthmus of Panama and portions of Costa Rica. Based upon a reconnoissance made for Alexander Agassiz. With special determinations by W. H. Dall, R. M. Bagg, T. W. Vaughan, J. E. Wolff, H. W. Turner and Ahe Sjögren. (Bull. Mus. Comp. Zool., vol. 28, Geol. ser. vol. 3, no. 5, pp. 149-285, pls. 1-19, June 1898.)

Hollick, Arthur.

Notes on Block island. (N. Y. Acad. Sci., Annals, vol. 11, pt. 1, pp. 55-88, pls. 2-9, Apr. 30, 1898.)

Kain, S. W.

List of recorded earthquakes in New Brunswick. (Bull. Nat. Hist. Soc. of New Brunswick, vol. 16, pp. 16-22, 1898.)

Marsh, O. C.

New species of Ceratopsia. (Am. Jour. Sci., ser. 4, vol. 6, p. 93, July 1898.)

Miller, A. M.

Natural arches of Kentucky. (Science, new ser., vol. 7, pp. 845-846, June 24, 1898.

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Osborn, H. L.

The extinct rhinoceroses. (Mem. Am. Mus. Nat. Hist., vol. 1, pt. 3, pp. 75-164, pls. 12a-20, Apr. 22, 1898.)

Osborn, H. F.

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PERSONAL AND SCIENTIFIC NEWS.

THE HAYDEN MEMORIAL GEOLOGICAL AWARD for 1898 has been conferred, by the Academy of Natural Sciences of Philadelphia, on Prof. Otto Martin Torell, director of the Geological Survey of Sweden. The award consists of a bronze medal and the interest on the endowment fund.

THE FOLLOWING NAMED GENTLEMEN received the degree of Doctor of Philosophy at the Johns Hopkins University in June, presenting the theses indicated:

Cleveland Abbe, Jr.: "The Rivers of Maryland With Special Relation to the Evolution of the Piedmont Topography."

A. G. Leonard: "The Basic Eruptive Rocks of Northeastern Maryland and Their Relation to the Granites."

C. C. O'Harra: "The Geology of Allegheny County, Including an Account of the Stratigraphy and Structure of the Central Appalachian Belt in Maryland."

Dr. Abbe becomes professor of geology at Western Maryland college, Westminster, Md. Dr. Leonard becomes a member of the Maryland Geological Survey. Dr. O'Harra becomes professor of geology and mineralogy at the South Dakota School of Mines.

THE INTERNATIONAL MINING CONGRESS which met at Salt Lake city, in July, had an attendance of about 200, representing mostly the mining states of the west, also Mexico, Peru, Canada, Venezuela and Australia. The next session will be held in 1899, at Milwaukee. One of the most important objects of the congress is to recommend amendments to the mining laws of the United States.

THE NATIONAL GEOGRAPHIC MAGAZINE, Washington, issued a specially adapted number for July, in recognition of the Washington meeting of the National Educational Association. It contains valuable articles suited to the higher grade teachers, on American Geographic Education by W. J. McGee; Origin of the Physical Features of the United States, by G. K. Gilbert; Geographic Development of the District of Columbia, by W. J. McGee; Historical Development of the national capital, by Marcus Baker; Geographic

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Work of the General Government, by Henry Gannett; and on the Geologic Atlas of the United States, by W. J. McGee.

EXTENSIVE IRON ORE DEPOSITS in Japan, have been discussed in "*Stahl und Eisen*," by Dr. Th. Mukai. They are chiefly magnetite and hematite; the amount now known is estimated at seventy million tons, and new deposits are continually being discovered. They are destined to have an important bearing on the industrial development of Japan.

STATE GEOLOGIST BLATCHLEY, of Indiana, in his last report calls direct attention again to the decrease in the natural gas supply. The productive area is about half what it was originally. The average rock pressure has fallen from 325 pounds to less than 200 pounds, and salt water is constantly encroaching toward the centre of the field.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE will hold its 50th meeting at Boston beginning August 22d. The president of the meeting is Prof. F. W. Putnam, for many years the efficient secretary of the Association. The retiring president is Prof. Wolcott Gibbs. The headquarters of the Association will be at the Massachusetts Institute of Technology. The section of Geography and Geology will be presided over by Prof. H. L. Fairchild, of Rochester, N, Y., and his address will be on "Glacial Geology in America." Its secretary is Mr. Warren Upham of St. Paul.

This meeting marks an epoch in the history of the Association and special preparation has been made to enhance the interest and value of the proceedings. Many attractions of scientific and social character center in Boston and will conspire with the unusual programs to cause a large attendance.

HARVARD UNIVERSITY. The departments of Geology and Geography, and of Mineralogy and Petrology, have a working faculty of fourteen instructors and professors according to a late circular. The organization of these departments, under professors Shaler and Wolff, and their scope of instruction, whether within the laboratory or in the field, place the institution in these departments in the fore front in America.

MR. R. A. DALY, after three years travel and study in Europe, has been appointed instructor in physiography in Harvard University, associated with Prof. W. M. Davis.

DR. GEORGE BAUR, OF THE UNIVERSITY OF CHICAGO, late of Clark University, Worcester, Mass., one of the most eminent and active of the younger paleontologists of America, recently died, having been absent from his work and seeking restoration of health during the past year. A brief sketch is in *Science* of July 15, by O. P. Hay.

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AMERICAN GEOLOGIST.

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[Continued from the March No.]

THE GEOLOGY OF THE KEWEENAWAN AREA IN NORTHEASTERN MINNESOTA. III.

By A. H. ELFTMAN, Minneapolis.

(Plate VII.)

Part II. GEOLOGY OF THE KEWEENAWAN SERIES.

The Map.

The accompanying map, Plate VII, represents the subdivisions of the Keweenawan series in Northeastern Minnesota. The boundaries of the various members represent the limits of the main body of each member. The Red Rock member is so intricately involved with the Gabbro member, that it is impossible to represent every small area of red rock within the gabbro mass, upon a map of this scale Owing to the heavy cover of glacial drift the exact location of the boundaries is known often only in widely separated areas. The numerous isolated outcrops of the several members of the series show the position of the main body of each member. In townships 63 and 64 N. R. 2 E., T. 63 N. ranges 3 and 4 E. and along the lake Superior coast from Brulé river to Red Rock bay, the writer has relied entirely upon previous descriptions and an examination of rock specimens from that region. The extensive diabase dikes between Grand Portage bay and Pigeon point, are probably of Keweenawan age. As no direct evidence to this effect is at hand

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it seems advisable to omit these at present. The same may be said of the Logan sills in the Animikie. In giving references, the numbers given in the text refer to the number of the article in the bibliography of the literature upon the Keweenawan area given in the March number of the Geologist.

Chapter III. The Gabbro Member.

Surface area. The gabbro forms the outer or northern member of the Keweenawan series. The general shape of the area is crescentic with the concave side towards lake Superior. The horns of the crescent are located, the one near Duluth and the other near East Greenwood lake, T. 64, N., R. 2 E. The chord connecting them is 125 miles long and runs northeast and southwest. The maximum width of the area is 25 miles. The surface area is about 2,400 square miles in extent.

The northern boundary of the gabbro is quite regular and comes into contact with all of the pre-Keweenawan formations recognized in northeastern Minnesota. In Ts. 49 and 50 N. R. 15 W. the gabbro is in contact with the Animikie slates of the Saint Louis river valley. Continuing northward the contact of the formations is concealed by glacial drift for the next sixty miles. In the vicinity of Birch lake, T. 61 N., R. 12 W., the gabbro is found in contact with the iron-bearing member of the Animikie. Within the next twenty miles northeast from Birch lake the contact is with the White Iron lake granite of pre-Animikie age. Extending eastward to lake Gabemichigama the gabbro cuts and lies upon the Lower Keewatin, Upper Keewatin and the Snowbank lake granite. Between Gabemichigama and Gunflint lakes the gabbro is in contact with the Animikie, Keewatin and some ancient greenstones (gabbros, etc.), probably of Archæn age. From T. 65 N. R. 4 W. to the eastern extremity the gabbro is in contact with the iron-bearing, black slate and graywacke slate members of the Animikie.

The southern boundary of the gabbro is irregular on account of the invasions of other members of the Keweenawan series. From the south side of East Greenwood lake the boundary passes westward for thirty miles and turns south and east through Brulé lake along the Brulé river valley to the east side of T. 63 N., R. 1 W. In the vicinity of Brulé Mt. and Eagle Mt. the limit of the gabbro zigzags and finally

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follows a southwesterly course, through section 6, T. 62 N. R. 2 W., and through section 15, T. 62 N. R. 4 W. on the east branch of the Temperance river; continuing westward it passes through the central part of T. 60 N. R. 6 W. between lakes Harriet and Bellissima; thence through the southeastern part of T. 60 N. R. 7 W. and between West Greenwood lake and Greenwood Mt., in T. 58 N. R. 10 W. At the last locality it turns sharply toward the south, passes near the northwest corner of section 19, T. 55 N. R. 11 W. and from there continues in a southwesterly direction to Duluth. Theses boundaries give the widest areal distribution of the gabbro. Within this area are other rocks, some of which are quite extensive and nearly all of a later geologic age. The chief area of this kind is the region west and southwest of Brulé lake.

Age of the gabbro. The gabbro has been assigned geological positions from the base of Animikie to the middle of the Keweenawan. Dr. W. S. Bayley (41, vol. I., p. 695) summarizes the various views and concludes that, "so far as the little evidence at hand enables us to judge, the gabbro * * * forms a great mass of enormous extent above the Animikie, but below the interbedded flows and fragmentals of the Keweenawan series in Minnesota." After a discussion of the petrographical characters of the gabbo in which the intrusive character of the rock is emphasized, Dr. Bayley concludes that, "further field work on the geological relationship of the mass will probably show either that it is a batholite within the Keweenawan series, well toward its base, or that like the anorthosites of Lawson it is an eroded 'massive' upon the top of which the later Keweenawan beds have been deposited."

All the writers upon this area, now agree that the gabbro is younger than all of the formations with which it comes into contact on its northern edge. The gabbro cuts across the strike of the several formations, penetrates and incloses fragments of them. In places the older rocks were completely changed at the time of the intrusion of the gabbro mass. On its southern edge the gabbro member is in contact with the later members of the series. The red rock member is the most common of the series. Large bosses and dikes of augite syenite and granite cut the gabbro near the contact of the main

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bodies of the two, and the red rock dikes run for several miles from the parent mass. In the vicinity of the isolated red rock bosses the gabbro is usually cut by dikes, from a few inches to ten feet in width, radiating from the central mass and increasing in number as the boss is approached. Gabbro dikes are not known to cut the red rock. In many localities large masses of gabbro and red rock are in contact, but without any evidence of their relative age. All the evidence, however, agrees that the red rock acts as an intrusive toward the gabbro, and that makes the latter an older rock than the red rock.

The Beaver Bay diabase is everywhere separated from the gabbro and so far as their relation to the other members of the series shows, these two may be regarded as contemporaneous rock masses. The Temperance River flows are largely separated from the gabbro. West of Duluth these flows are unconformably above the gabbro. The later diabase cuts the red rock and gabbro. The evidence thus shows that the gabbro is above the Animikie or Upper Huronian, and that it is the lowest or oldest member of the Keweenawan series.

Structure. The gabbro forms an enormous crystalline mass varying in structure from a homogenous massive to a banded and apparently bedded rock. The tendency to segregation into large masses composed chiefly of one or only a part of the minerals is well brought out. The various stages of segregation are clearly defined and appear in the following order:

1. A homogeneous rock in which all of the minerals present are uniformly distributed.

2. The feldspars, the ferro-magnesian and iron-bearing minerals become separated into aggregates giving a peculiar spotted appearance to the rock. The diallage and olivine form clusters of grains sometimes radially arranged. These clusters vary in diameter from one to four inches. The plagioclase which makes up the greater part of the rock also fills the spaces between the diallage and olivine grains, and thus serves as a matrix of these minerals.

3. In many places the gabbro possesses a marked banding. This consists of alternating layers of different mineral composition, rendered conspicuous by the color of the min-

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erals. The bands have no general direction of strike and dip, appear and disappear at random. Some of the bands are composed of the normal phase of the gabbro; while others are composed on the one hand almost wholly of feldspar and of the ferro-magnesian minerals on the other. The bands vary in thickness from less than an inch to several feet. Each band is usually quite irregular, varying considerably in thickness in different parts. The lines of division between the different bands usually appear quite sharp and distinct on surface exposures. A microscopical examination of the different bands shows that the mineral constituents are the same in all of them, yet in quite different proportion. The texture of the different bands is usually the same and the minerals of each band are intimately united with those of the adjacent bands, indicating that they were solidified at the same time. The banding is similar to that described and illustrated by Geikie and Teall in the Tertiary gabbros on the Isle of Skye.*

4. Frequently considerable areas of the gabbro consist chiefly of one mineral. Prominent illustrations of this are the feldspar masses in the central part and the magnetite masses near the edges and in the eastern end of the gabbro area. There are all gradations in size from these large masses to the banded and homogeneous rock. The large feldspar masses frequently contain patches 10 to 100 feet in diameter, of the normal phase of the gabbro. While the outlines of these enclosed patches is sharp in places, it usually grades gradually into the feldspar rock. In approaching one of the feldspar areas the normal massive rock at first shows a spotted and then a banded structure, which continues up to the isolated mass. The magnetite deposits are surrounded by similar conditions. The normal rock becomes banded by a separation of the feldspar and magnetite. The latter bands sometimes increase in thickness to over 200 feet in width or widen in places, forming large lenticular and boss-like masses surrounded by the normal phase of the gabbro.

5. The mineral constituents sometimes are arranged with their longer axes parallel or lying in one plane. The different minerals are proportionately distributed or are separated into

*Quart. Jour. Geol. Soc. London, 1894, No. 200, pp. 645-660.

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thin bands. The whole produces a gneissic structure similar to that found in granites. This structure was seen particularly in the northeast corner of T. 61 N., R. 10 W. and north of West Greenwood lake, T. 58 N., R. 10 W.

The preceding structures of the gabbro are primary conditions incident to the solidification of the gabbro magma. Frequent reference has been made by other writers to the bedded or sheeted structure of the gabbro. This has been the chief argument in favor of considering the gabbro mass as composed of separate surface flows. The structure is a fissility produced by dynamic forces acting upon the gabbro mass after its solidification. The strike of the layers is nearly northeast and southwest, but there is a tendency to conform in direction to the outer limits of the gabbro. The prevailing dip is 20 to 45 degrees to the southeast or 20 to 45 degrees to the northwest. Occasionally the two sets of fissility or cleavage are found in the same locality and the rock then breaks into cubes or rhombs instead of splitting into large slabs. The fissility traverses the rock irrespective of the direction of the primary structures. When these structures have the same strike and dip as the fissility the two coincide. A difference in dip of 10 degrees between these structures will make both visible. The fissility is common to all parts of the gabbro. The layers vary in thickness from one inch to ten feet. Cliffs which possess the fissility and which have been subjected to extensive weathering have the appearance of a wall of masonry.

Texture. The size of the minerals constituting the gabbro varies from fine grained to very coarse grained crystals and crystal grains sometimes six inches across. The usual size is medium to coarse grained. The prevailing texture of the gabbro is the granitic. The other textures are developed only locally and seldom of great extent. The granulitic texture is limited to certain contact phases of the rock, and is especially well developed along the northern edge and in the vicinity of Brulé lake. It is the texture common to the fine grained parts of the gabbro.

The poikilitic texture is rarely found in the relations of the essential minerals to each other. The accessory minerals are frequently enclosed within the larger grains of the essential minerals.

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The ophitic (lustre-mottling) texture is found only rarely. This consists of large grains of diallage enclosing numerous feldspars similar to the ophitic texture common in the diabases.

The pegmatitic texture is not known as an original texture in the gabbro. It is common in certain altered phases of the rock, and consists of the alteration of the feldspars and a subsequent replacement of the altered parts by quartz which is similarly oriented throughout each feldspar grain. This process, when completed, gives the appearance of two minerals originally crystallized within each other. The fibrous intergrowth of minerals, common in the gabbro, may be a species of original pegmatitic texture. It consists of minute fibers of pyroxene and feldspar extending from the crystalline grains of both minerals, and lying side by side, forming a fibrous aggregate. Under a high power these fibers are shown to be forms of incipient crystallization branching out from the larger grains and restricted in their growth by a mutual contact.

Minerals. The primary constituents of the gabbro are, plagioclase, orthoclase, diallage, hypersthene, augite, olivine, magnetite, garnet, apatite, pyrite, native copper, chalcopyrite and graphite. The secondary minerals are hornblende, biotite, chlorite, epidote, quartz, hematite, limonite, leucoxene, kaolin, serpentine, calcite, malachite, azurite.

Plagioclase is the most abundant component. The mineral occurs in broad grains with a fairly regular outline. Nearly all of the grains possess broad twinning lamellæ easily seen upon a freshly broken specimen. The color varies from the clear, colorless fresh mineral to the milky white color of the highly altered mineral. The cleavages are always prominent and show the striated surface due to the twinning. Under the microscope, twinning, according to the albite law, is common, and according to the pericline and Carlsbad laws rarer. The extinction angle varies in different individuals from 20 to 40 degrees, indicating the presence of labradorite, bytownite and anorthite. The acicular inclusions characteristic of gabbroitic feldspar are nearly always present. They are sometimes parallel with the longer axis of the crystals. Each feldspar usually has several sets of parallel inclusions which cross each other at various angles. In many sections

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the feldspars are filled almost to opaqueness with dust-like inclusions, which, under a high magnification, appear as minute crystals whose identity cannot be determined. Small grains of pyroxene, olivine and magnetite are also inclosed by the feldspar.

Dr. Bayley (41, Vol. I., p. 700) has shown that the chemical composition and the mean density of the feldspar corresponds very closely to that of a basic labradorite. The plagioclase is generally quite fresh. Alteration proceeds around the edges and along cleavage and fracture lines. The usual product is kaolin, which appears in fine specks. In some grains the white alteration product assumes a fibrous form, but the nature of the mineral cannot be determined.

Orthoclase occurs sparingly in the gabbro at Duluth and along its southern limits. It is indicated in the hand specimens by its red color due to weathering or when fresh by a dull white color. The presence of potassium in the rock is shown by chemical analyses.

Diallage is present in irregular, rounded and angular anhedrons often two to six inches across. The color is usually dark brown, varying to pink, which variation may be due to incipient alteration. The crystal grains are always traversed by parallel cleavage lines parallel to the axis c. There is also a distinct parting which cuts the cleavage at an angle of 15 degrees. Pleochroism is absent. Polarization colors are high and the maximum extinction angle is 39 degrees, when measured from the cleavage parallel to c and about 25 degrees when measured from the parting, which is easily mistaken for cleavage. The mineral has a strongly developed fibrous structure. Numerous tabular inclusions characteristic of gabbro diallages occur in many grains. Sometimes they form parallel bands crossing the crystals. The diallages are usually associated with the augite, olivine and magnetite.

Hypersthene occurs as small rounded grains in the granulitic phases of the gabbro and as large irregular anhedrons, frequently one-fourth of an inch in length, in the coarser noryte. The color is black to brown in the hand specimen, and light brown in the thin section. Cleavage lines parallel to the axis c are prominent. Fracture lines are not numerous, and when present occur as irregular lines through

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the crystal. Twinning has not been noticed in any of the sections. Pleochroism is strong as follows: **c** = light green, **a** = brownish red, **b** = greenish yellow or pink to red. Polarization colors are low and the extinction is parallel on every axis. The tabular microlitic interpositions usually found in hypersthene are almost wanting in the mineral in this rock. These, like the tabular inclusions in the diallage, are doubtless due to alteration.

Augite occurs in subordinate quantity as irregular anhedrons. The color is usually light brown, varying on the one hand to dark brown in which each grain is uniformly colored throughout, and on the other to almost colorless. The mineral is everywhere traversed by parallel cleavage lines and numerous irregular fractures with no definite direction referred to the cleavage. There is no perceptible pleochroism. Polarization colors are high and the maximum extinction on the brachypinacoid is about 54 degrees.

Olivine is present as irregular grains having frequently partial crystal outlines. It is surrounded by the pyroxenes, and when these minerals are present in the rock the olivine seldom comes into contact with the feldspar. The rim of pyroxene is sometimes scarcely noticeable and from this narrow extent increases until it forms large plates. Inclusions of magnetite are nearly always present, and locally are so numerous as to render the olivine opaque. In some sections the magnetite assumes a vermicular form, which, on account of its being found in the perfectly fresh mineral, is probably primary. A dendritic form of the magnetite is sometimes associated with the alteration products of the olivine, and is probably secondary. The color of the olivine is greenish to yellow. The mineral may be recognized in the hand specimen by its yellow, wax-like color when fresh, and by the brown, earthy appearance when altered. Cleavage lines are absent, but numerous irregular fracture lines are prominent. In thin section the surface of the mineral appears rough on account of the high index of refraction. Pleochroism is absent, polarization colors are high and extinction is parallel. The mineral is usually quite fresh in all phases of the gabbro. In the forellenstein it is more or less altered and the usual lattice structure accompanying alteration is very prominent.

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Bayley has shown that the olivine is a hyalosiderite with Mg: Fe about 1½ to 1. Small quantities of the rarer metals, manganese, cobalt, chrominm and nickel also occur in this mineral.

Magnetite is scattered throughout the rock. Ordinarily it occurs in small grains usually having perfect crystal outlines. Large irregular areas, making up a large part of the rock, are found in some sections. The proportion increases until the entire rock is composed of this mineral. Chemical examinations show that the mineral is sometimes free from titanium, but usually the latter constituent is present in varying amounts up to 20 per cent.

Apatite is present only in a small quantity. It occurs as small greenish to colorless crystals enclosed in the other minerals of the rock.

Pyrite is common in some parts of the rock. It occurs in irregular aggregates sometimes an inch across and in thin sections it appears as small yellow cubes. It is commonly associated with the magnetite.

Chalcopyrite appears as brass yellow grains or aggregates associated with the pyrite found in the magnetite deposits. The mineral is not abundant and seems to be developed only locally.

Native copper occurs as small strings or grains enclosed by the other minerals. Occasionally small grains of copper are imbedded in the clear plagioclase, and again fine threads of copper unite several plagioclase grains. Some hand specimens show copper up to five per cent of the whole mass.

Graphite occurs as nodules and micaceous grains in the gabbro at its contact with the black slate member of the Animikie. The mineral is derived from the carbonaceous material in the slate, and seldom is found far within the gabbro. It has a gray color. When wet the nodules may easily be cut with a knife, upon exposure to the air and when dry the graphite becomes hard and brittle.

Garnets occur sparingly in small red grains near the contact with the older rocks and near some of the magnetite deposits.

Hornblende is never found in the perfectly fresh rock. It is always associated with the diallage and augite. There

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are all gradations from a narrow rim of hornblende around a plate of pyroxene, or a few small areas of hornblende within the pyroxene to a plate of hornblende with a few scattering areas or a single core of pyroxene. Some sections of the highly altered rock contain only hornblende, but in several sections from the same hand specimens there is nearly always some trace of diallage. Since the hornblende is always closely associated with the pyroxene and since it is absent from the unaltered rock it is concluded that the hornblende in the gabbro is always of secondary origin. The mineral has a light to dark green color. Pleochroism is strong and the maximum extinction angle is about 22 degrees. The columnar structure of uralite is prominent. Frequently the mineral is finely fibrous.

Biotite is common in the altered parts and absent in the fresh portions of the gabbro. It occurs as thin scales and irregular crystals sometimes two to three inches across. The outer parts of some of the large pyroxene crystals consist of biotite. In thin section it is seen surrounding plates of pyroxene and hornblende. These three minerals are sometimes found in the same individual, the biotite forming the outer rim, the hornblende the middle and the pyroxene the inner core. The biotite also forms a mosaic with highly altered pyroxene and hornblende. It occurs as a reaction product between magnetite and plagioclase. Small flakes of the mineral within the feldspars indicate the former presence of magnetite. Instead of single plates replacing the pyroxene there are in some sections beautiful rosettes of biotite. The mineral varies from a dark brown to reddish brown. The latter color is found chiefly in the biotite surrounding the magnetite. Cleavage is nearly always prominent. From its association of biotite with the other minerals it is undoubtedly always secondary.

Chlorite occurs as an alteration product derived largely from the ferro-magnesian constituents of the rock. It is present in minute greenish flakes and needles sometimes arranged in rosettes and fibrous aggregates, which, between crossed nicols, show a dark cross.

Epidote, like chlorite, is not abundant, and occurs as an alteration product. It is present in the altered feldspar, and other minerals, as minute yellow flakes.

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Quartz is abundant as a secondary mineral in some of the altered phases of the gabbro. It is never present in the fresh rock. With the feldspar it forms a pegmatitic texture like that found in the augite syenite of the red rock member described by Irving (14, p. 114). In some sections grains of feldspar are entirely replaced by quartz, which then has a typical granitic texture. There are all gradations in texture between the feldspar and the quartz. The former in some sections shows only a few small specks of quartz, which becomes more abundant until the feldspar is entirely replaced. The quartz has also been formed between crystals of feldspar, in which case it replaces some of the other minerals. In some sections it is filled with minute inclusions of a dark substance.

Hematite occurs as small red flakes and as an earthy decomposition product in some of highly altered gabbro. When the iron bearing minerals are abundant the hematite gives a brick red color to the rock.

Limonite is present as a yellow earthy decomposition product. It is noticeable in small quantities in nearly all sections which show alteration.

Leucoxene occurs in small quantities as an alteration product of the titaniferous magnetite. It has been noticed as a white powder in some of the highly altered magnetite masses, and in thin sections it is found as a white border around some of the magnetite grains.

Kaolin is present as decomposition product from the feldspar. It is present usually in fine flakes within the feldspar. In some parts of the decomposed rock the feldspar is entirely altered to kaolin, which then forms a dull white substance easily powdered.

Serpentine is the usual alteration product of olivine, and is abundant in the forellenstein. It occurs as a fibrous substance often stained red by iron oxide.

Calcite occurs in small veins in the gabbro, and is the result of alteration in the rock. Some of this mineral may be derived from outside sources, but part of it, which is associated with the decomposed rock, is probably derived directly from the gabbro.

Malachite occurs as a green coating upon the rock and in fractures in localities where copper and chalcopyrite occur in the gabbro.

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Azurite occurs as a blue coating derived from the copper-bearing minerals.

Varieties. The entire gabbro mass consists of minerals common in gabbros. These minerals vary in proportion in different parts of the rock. There is every gradation from the uniform mixture of minerals to masses composed entirely of one mineral or in which the other minerals may all be present but forming only a small per cent of the whole. While the whole rock is included under the general term gabbro, it seems that the various mineral combinations which have persistent characters are of sufficient importance to merit varietal names. The separating into varieties is due to forces acting at the time of solidification. The principal minerals are nearly always present either as essential or accessory, according to the variety.

Normal phase of the gabbro. This phase of the rock consists essentially of plagioclase and diallage. The former is more abundant. Olivine is nearly always present as an accessory mineral. Since the absence of olivine is only exceptional it appears that the division into olivine and olivine-free gabbros is wholly superfluous in the Minnesota gabbro. Augite and magnetite are never present in large quantities. The prevailing texture is coarse grained with the average size of the grains between one-eighth to one-fourth of an inch across. While the minerals are usually in broad plates, frequently they occur as long, narrow individuals similar to those found in diabase. All of the mineral constituents can generally be identified in the hand specimen. The prevalent color is light gray on the freshly fractured surfaces and dull white on exposed surfaces.

Forellenstein (troctolyte). The olivine in the normal phase of the gabbro varies in inverse proportion with the diallage. When the olivine predominates over the diallage, the other constituents remaining the same, the rock approaches the character of a typical forellenstein. In many areas of the gabbro, notably in T. 61 N. R. 10 W. and adjacent townships, the olivine has nearly replaced the diallage, which occurs only in a very subordinate quantity. The rock has a spotted appearance and is usually characterized by a banded structure. The olivine, when altered, changes to serpentine

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and red earthy iron oxides, which are often sufficient to give the rock a brick red apeparance. The prevalent color is dark brown. The feldspars surrounding the altered olivine are always filled with fractures arranged radially around the olivine. According to Prof. Judd, this shattering of the feldspar is produced by the hydration of the olivine, during which process, on account of the increase in the bulk of the mineral, there is an expansion on this part of the rock, and a fracturing of the unaltered minerals around the olivine.*

Noryte. Hypersthene is frequently present as an accessory mineral in the gabbro mass. It sometimes predominates over the other pyroxenes and olivine, even being the only ferromagnesian mineral present. The rock then becomes a noryte. Around West Greenwood lake in T. 58 N. R. 10 W. this rock is extensively developed. It is coarse grained and unaltered. The color is light gray with brown spots evenly distributed. The texture is granitic. The noryte occurs quite extensively along the northern border of the gabbro, where it was recently described by Bayley (41, vol. III., pp. 1-20). The texture of the rock there is granulitic and is regarded as a phase of the gabbro due to contact phenomena. In section 21, T. 63 N. R. 4 W. and in the region west of Brulé lake there is also an extensive development of the granulitic noryte. This rock is fine grained and usually has a darker color than the normal phase of the rock. In the last named localities it is intimately associated with the magnetite deposits of that vicinity.

Anorthosyte. This is ccmposed essentially of plagioclase with the other mineral constituents as accessory. The usual proportion being 90 to 95 per cent of plagioclase and 10 to 5 per cent of pyroxene, olivine, magnetite, etc. This rock is apparent in the central part of the gabbro area, and it has been noticed especially south and west of Little Saganaga lake, T. 64 N., R. 5 W., and for fifty miles westward of that locality as far as the gabbro remains uncovered. The anorthosyte has a white color and usually stands out quite prominently from the other phases of the gabbro.

Pyroxenyte. When the rock is composed entirely of the pyroxene minerals it is dark in color and much heavier than

*Quart. Jour. Geol. Soc. London, 1886, No. 165, vol. XLII, p. 86.

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the normal phase of the rock. The next variety is generally closely associated with this.

Peridotyte. This consists chiefly of olivine together with some pyroxene. The pyroxenyte and peridotyte are quite limited in extent. The rocks of this variety found along the northern boundary of the gabbro are not part of that rock, but are referred to the contact action of the gabbro upon the older rocks.

Magnetite. Small masses of titaniferous magnetite are scattered throughout the gabbro. Extensive masses are known only along the northern border and in the eastern part of the gabbro. These deposits of magnetite are especially numerous in the region between Brulé lake and the northern limit of the gabbro. The ore bodies are found in three belts running east and west. The northernmost follows the boundary of the gabbro. The second runs through the southern part of township 64 north, and the southern or third belt runs south of Brulé lake through the central or southern part of township 63 north.

The magnetite deposits are usually associated with granulitic noryte, which is always slightly the older of the two. The noryte is considerably broken and traversed by veins of magnetite extending from the large masses around its edge. From the main mass of the magnetite, stringers and apophyses run several hundred feet into the massive gabbro. Frequently the magnetite occurs in numerous parallel bands several inches to a foot in width, which alternate with bands of the associated gabbro. As many as twenty-five of these bands have been noticed within a belt ten feet wide. There are all proportions of minerals between magnetite and the normal phase of the gabbro. The variations of the ore as seen in a shaft 19 feet deep on section 21, T. 63 N., R. 4 W., is as follows: At the surface the rock was composed of solid coarse magnetite stained green with a coating of malachite. The pure magnetite continued downward for five feet when a few grains of chalcopyrite, pyrite and plagioclase were found. At seven feet below the surface the magnetite became fine grained, and a small amount of plagioclase and pyrite continued. Olivine appears as bright, yellow grains. Continuing downward the plagioclase and pyrite disappeared and the lower ten feet of the

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shaft were in magnetite with the olivine increasing in proportion.

The ore has a shining black luster, is brittle and usually coarse grained. Thin sections of the apparently pure ore generally show the presence of small particles of plagioclase, and sometimes of other minerals. Copper and chalcopyrite are associated with magnetite. Native copper was found by the writer in outcrops north of Tucker lake in the north part of T. 64 N., R. 3 W., and from the shaft in the N. W. ¼ of S. E. ¼ sec. 21, T. 63 N., R. 4 W. It is reported from other localities near these locations. Some specimens of rock contain over five per cent of copper.

Chemical analyses show quite a variation in the composition of these ores. An analysis by the writer of an ore from section 21, T. 63 N., R. 4 W., gave silicia, 6.08; alumina, 3.82; lime, 1.69; titanium oxide, 14.73; magnetite, 71.; nickel oxide, 2.65; sulphur, trace. The lime and alumina are accounted for by the presence of a triclinic feldspar.

Titanium is sometimes absent. Cobalt, manganese and chromium are sometimes found in addition to the constituents given in the above analysis. The metallic iron varies from 49 to 60 per cent. These extensive magnetite deposits at present afford the only ores from the gabbro of probable economic value. An exhaustive study of the rarer metals in this ore has not yet been accomplished. Some analyses show the presence of small quantities up to two or three per cent of these metals in certain localities.

Orthoclase gabbro. This variety is so called on account of the presence of the mineral orthoclase. Since this mineral is never abundant the orthoclase gabbro is quite limited in extent. It seems that the orthoclase might be regarded as an accessory mineral rather than to form a separate variety.

It is hard to distinguish the relative age of each variety. The granulitic noryte is slightly older than the rest of the mass, which may be considered as of one age. The noryte in places forms angular blocks cut by and enclosed in the rest of the gabbro. In other places the noryte and gabbro grade into each other. The relative age of the individual minerals may assist in determining the relative age of the varieties of the gabbro mass. The minerals were formed in the following

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order: Apatite, magnetite, olivine, hypersthene, augite, diallage. The plagioclase seems to be contemporary with the other minerals. The magnetite, while beginning to form before the olivine, did not cease to form until some time after the latter began. Since the olivine is usually surrounded by the pyroxene, its crystallization was apparently completed before the remaining minerals were formed. Hypersthene next began to form and continued after the augite began. The augite usually surrounds the former, but small grains of augite are also enclosed by some of the hypersthenes. The pyroxenes and plagioclase probably began to form about the same time. So far as the relation between the two shows, it seems that the plagioclase whose outlines depend upon the irregular anhedrons of pyroxene is younger than that part of the pyroxene, and that the plagioclase enclosed by the ophitic areas of pyroxenes is older than the latter mineral. There is no evidence that there was a cessation in the crystalization of the rock, but it seems that the process was continuous.

Alteration. —The alterations of the minerals are as follows: The pyroxenes change directly into hornblende, and biotite. The hornblende also changes to biotite. Olivine forms serpentine. Plagioclase is replaced by quartz and kaolin. Biotite forms a reaction product between plagioclase and magnetite. Chlorite, epidote, iron oxides, kaolin, leucoxene, serpentine, calcite and the copper carbonates are decomposition products.

The alteration of the mineral components of the gabbro, locally sometimes proceeds far enough to form a rock whose mineral composition is quite different from that of the original gabbro. An example of this is found at places along the southern edge and in the eastern end of the gabbro area. The rock is originally composed essentially of plagioclase, orthoclase and pyroxene. The pyroxene is changed to hornblende and biotite. The feldspars are in part decomposed into kaolin and silica. Quartz replaces the decomposition products. The rock is then composed essentially of plagioclase, orthoclase, quartz, hornblende and biotite, and becomes a granite in composition. In the field it is sometimes difficult to mark the boundary between this altered phase of the gabbro and the augite syenite of the red rock member.

Contact Phenomena. —The gabbro presents remarkable

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contact phenomena along its northern edge. The older rocks with which it is in contact are nearly always highly changed from their original condition. The following localities exhibit the most conspicuous exposures of contact:

T. 65 N. R. 3 W. At the western end of Loon lake the gabbro lies upon the graywacke slate members of the Animikie. This is a sandstone and quartzyte. At the contact and for ten to fifty feet from the gabbro the quartzyte is completely changed and consists of irregular, angular and interlocking grains of quartz, having a typical granitic structure. Hornblende and biotite occur in large plates and surround quartz grains as a matrix in a poikilitic manner. Other parts of the Animikie at this locality have been changed to a biotite schist. The gabbro has a uniform coarse grained texture.

Akeley lake, T. 65 N. R. 4 W. Here the gabbro is found in contact with the iron bearing and black slate members of the Animikie. These members are entirely recrystallized by the effect of the gabbro. The iron bearing member forms a coarsely crystalline rock composed of quartz, pyroxene, olivine and magnetite. The black slate member was changed into biotite schist, and crystalline quartz rock. The carbonaceous matter was collected as graphite which occurs extensively in the contact zone. The gabbro of this locality is a uniformly coarse grained normal phase of the rock.

T. 63 N. R. 8 W. South of Disappointment lake the gabbro is in contact with a conglomerate and beds of iron ore. The older rocks are entirely recrystallized though retaining their stratification to a remarkable degree.

Sec. 30, T. 62 N. R. 10 W. In this locality large blocks of a quartzose pyroxene magnetite rock, like that at Akeley lake, occur in the gabbro two miles from its northern border.

Birch lake, T. 61 N. R. 11 W. North of the lake the gabbro is in contact with quartzose pyroxene rocks, which extend westward and are found to be a part of the iron bearing member of the Animikie. (43, pp. 159-169.) Southwest of the lake the gabbro produced biotite schists at the contact with the Animikie rocks.

Many of the quartzose, pyroxenic and olivinitic magnetites occuring at the preceding localities have been regarded by Bayley (41, Vol. II, p. 814), as peripheral phases of the gabbro.

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The writer excludes these rocks from the gabbro for the following reasons:

1. These magnetite rocks are stratigraphically continuous with the Animikie iron bearing rocks, and at Birch and Akeley lakes the unchanged rock can be traced by successive steps into the crystalline rocks, composed of quartz, pyroxene, olivine and magnetite. The metamorphosed rock retains the banded structure of the original rock. The rock is free from titanium. The chemical composition of the recrystallized rock corresponds closely with that of the unaltered rock.

2. The gabbro always acts as an intrusive toward the quartzose pyroxene rocks, the contact between the two is sharp. Large irregular blocks of the latter rock are entirely surrounded by the gabbro. The gabbro is nearly always a uniformly coarse grained normal phase when found in contact with the older rocks. The gabbro magnetites nearly always contain considerable titanium.

[European and American Glacial Geology Compared. VIII.]

RAISED SHORELINES AT TRONDHJEM.

By WARREN UPHAM, St. Paul, Minn.

The younger Hugh Miller visited the city of Trondhjem* in October, 1884, and, in a paper read before the British Association in 1885, reported his identification and mapping of forty-three raised shorelines, eroded in slopes of glacial drift below the very remarkable shore, 525 feet above the sea, which is eroded in the rock of the hill about a mile west of the city. Above a little bay at Leangen, two miles east of Trondhjem, Miller noted thirty shorelines in the first 300 feet of ascent from the fjord to a distance of one mile and a half from its shore. Three or four others were found in the next 50 feet

*Also often spelled Throndhjem by English writers. Its meaning is the *Throne Home*, having been for centuries the capital of the country. It is still honored as the place of coronation of the kings of Norway and Sweden, the present King Oscar II being crowned there in 1872.

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of ascent, and nine or ten others higher, before reaching the level of the sea-cliffs of rock.*

Remembering these published observations, I wished to see Trondhjem, not only on account of its historical interest as the ancient capital of Norway, but also for personal examination of these Late Glacial shorelines. Four days, July 17th to the 21st, 1897, were spent there, at the latitude of 63° 25′, about 210 miles south of the Arctic circle, this being the most northern part of our journeying. The temperature was delightful, warm but not hot; and the very clear air permitted extensive views from the adjoining high hills, looking far to the north and northeast along the great Trondhjem fjord, which takes its name from this city built on its southern shore at the mouth of the river Nid. During the time of our stay the city was thronged with its 30,000 people and many visitors, in the festivities of celebrating the nine hundredth anniversary of its foundation. King Oscar arrived from Stockholm for this celebration on the 17th, and remained three days. Though it was a month after the summer solstice, the days were still very long, the sun rising soon after two o'clock and setting a quarter before ten. On the evening of the 20th the bright and long continuing sunset illumination of the clouds was magnificent. The preceding evening I had returned very late from a walk of about twenty miles, and found that at midnight the twilight was sufficient for reading a book or newspaper.

The shoreline mentioned as worn in the rock (gneiss, mica schist, diabase, etc.) of this vicinity, marking probably a prolonged stage of the depression of the land at the time of the final retreat and departure of the ice-sheet, is best exhibited on the east slope of the rugged, mostly wooded hill named Gjeitfjeld, which rises steeply from the southwest shore of the fjord. In several places along a distance of about a mile, the more outstanding portions of this hillside, which is seen in full view from Trondhjem, looking west, are eroded into pre-

*Nature, XXXII, 555, Oct. 8th, 1885. This paper gives the altitude of the "upper line" of the raised sea-cliffs of rock as 580 feet, referring probably to the upper part of the cliffs. Their base, where the rock was undercut by waves and floating ice at the old sea level of the Champlain epoch or closing part of the Ice age, is 160 meters (525 feet) above the sea, as shown on the contoured map of Trondhjem and its environs published there by A. Bruns, in 1885.

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cipitous cliffs of bare rock from 25 to 75 feet high, their somewhat indefinite bases being approximately 525 feet above the fjord; but between the sea-cliffs slightly indented parts of the old shore, comprising together more than half of the same mile of distance, are not distinguished from the general wooded slope. Against this shore the waves raised by northeast winds, blowing unimpeded for nearly thirty miles down the fjord, doubtless bore much floe ice and the fragments of bergs discharged from the receding ice-front in water which then was 600 to 2,000 feet deep. Other parts of the shores of the Trondhjem fjord and its branches, both west and east of the city, seen along an aggregate extent of more than fifty miles, rarely exhibit this ancient shoreline conspicuously; and indeed it is not recognizable in any general view, but would require a survey with levelling for its accurate location, along nearly all its course.

It is well displayed, however, on the fjordward sides of two small hills, named Blybjerget and Sverresborg, which stand respectively close west and east of the road that ascends southwesterly from Ihlen, the western suburb of Trondhjem, at the distance of three-fourths of a mile from Ihlen and the present fjord shore. A nearly vertical rock cliff, about fifty feet high, bounds the north and west sides of the flat-topped Sverresborg, which is so called from its having been the site of a castle of King Sverre, 700 years ago. At the foot of the cliff a grassed terrace, partly encumbered by fallen rock masses, has a width of fifty to sixty feet along its extent of an eighth of a mile; and from its verge a talus descends some fifty feet to the margin of a cultivated field. On the opposite hill, Blybjerget, at the same level of about 525 feet, a gravelly and sandy terrace, mostly three or four rods wide, but in part, where it is built out northeastward by converging currents, ten to fifteen rods wide, reaches nearly a quarter of a mile. The higher hilltop is wooded; the old shore terrace is a narrow grassy pasture; and the slope below is mowing land.

Maps of Trondhjem and its vicinity usually show the rock-cut shore west of the city, designating it as a "strandline," and representing its sea-cliff and terrace as continuous, instead of which they are interrupted by longer parts of the old shore which are not distinctly eroded. The amount of wave work at

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the 525 feet level, however, appears to surpass that of any single one of the thirty successive shores of the glacial lake Agassiz. It was therefore my expectation, suggested by Miller's paper, that clearly marked beaches, similar to those of lake Agassiz and of the glacial lakes in the basins of the present great lakes tributary to the St. Lawrence, or like those of Glen Roy, would be found wherever drift-covered slopes descend from the level of the rock strandline. Such slopes, well adapted for the formation of shorelines, whether by erosion or by the accumulation of beach ridges of gravel and sand, were examined upon large areas near Trondhjem, also west and south of the adjoining hilly tract which culminates in Graakallen (1,840 feet, about four miles west of the city), and on the south side of the fjord along the route of the railway passing eastward. But well defined shorelines were observed in only a few places, and then only for short distances, chiefly where inflowing streams brought small delta deposits, or where some exceptionally favorable outline of the shore in its relation to the waves and currents permitted a short beach ridge or terrace to be formed.

Stages of pause in the emergence of the land are only very indistinctly and doubtfully shown by these deltas and beaches; and the correlation of their fragmentary development, so as to trace any shore continuously even on the most favorable drift slopes, is possible only by levelling across many tracts unmarked by shore erosion or deposition. In contrast with the usual continuity and clearness of the lake Agassiz and Glen Roy shores, my observations suggest that the time occupied in the re-elevation of the region of Trondhjem from its Champlain subsidence was probably more brief than the duration of these glacial lakes in North America and Scotland. The Recent period, as indicated by the present shorelines appears to have greatly exceeded the short time of continuance of the Champlain depression of this part of Norway after its ice burden was melted away.

In southern Sweden a most instructive series of Glacial and Postglacial epeirogenic movements has been ascertained

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by Baron De Geer.* From its high preglacial elevation the land there sank in the later part of the Glacial period much below its present hight. It was then re-elevated to such extent that the Baltic sea became a great freshwater lake. Next it was again depressed lower than now, and at present it is slowly rising.

The Late Glacial or Champlain subsidence was greatest on the west side of the Gulf of Bothnia, attaining there a maximum of 885 feet at the highest observed limit of its raised shorelines, and in the interior of the peninsula it doubtless exceeded 1,000 feet; but its amount decreased outward on all sides, being in the vicinity of Trondhjem about 525 feet, and much less on the outer parts of the Norwegian coast. In northern Denmark, I observed the very conspicuous Champlain shoreline from four to eight miles south of Frederikshavn, where it is marked by a continuous sea-cliff forty to seventy-five feet high, eroded in morainic till, with its base, which was at the old sea level, about forty feet above the present seashore.

Whether the Trondhjem district has experienced the full series of pendulumlike oscillations in the relations of land and sea which are definitely known in the south part of this peninsula, being carried upward from the Champlain depression higher than at present, then sinking, and now again rising, can probably be determined by careful mapping and study of the modified drift in the Gula, Nid, and Stjördal valleys, tributary from the south and east to the Trondhjem fjord and its arms. These valleys, in large part narrowly enclosed by high and precipitous mountains, bear on their sides numerous terraces of gravel and sand up to hights of 100 to 300 feet, or more, above the streams; and at somewhat greater altitudes they often display little delta areas of the same modified drift, level and cultivated on their extent of perhaps one or two acres, while all the adjoining valley side is rugged rock with a

*On Scandinavian Changes of Level during the Quaternary Period, Report No. 98 (Series C) of the Geol. Survey of Sweden, 66 pages, with maps, 1890; Bulletin, Geol. Soc. of America, III, 65-68, with map, 1891; Proc. Boston Society of Natural History, XXV, 454-477, 1892, (also in the Am. Geologist, XI, 22-44, Jan., 1893); On the Geographic Conditions of Scandinavia after the Ice Age, Report No. 161 (Series C), Geol. Survey of Sweden, 160 pages, with 29 text illustrations, and six map plates, 1896.

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scanty forest growth of dark firs and occasional white birches. The gravel and sand terraces and deltas, occurring at all hights up to the old sea level (and less plentifully represented at slight altitudes above the bottoms of the valleys along their upper courses before reaching the Champlain level), record much of the history of the glacial recession and the concurrent uplifting of the land from its subsidence. The lack of large alluvial areas at the mouths of these rivers seems to testify that the re-elevation at first surpassed the present hight; but to learn all the details of the epeirogenic oscillations, with pauses, which the region has undergone, so far as they can be read in these valleys, would require probably a whole summer of field work.

The most important comparison with America that I discern for the Trondhjem raised shorelines consists in their scantiness, which is fully paralleled by Maine, the Eastern Canadian provinces, and the St. Lawrence valley. Although the land there at the close of the Ice age was on large coastal tracts 300 to 600 feet lower than now, as in Norway and Sweden, its emergence occupied too brief time to allow the waves to carve the shores deeply or amass well developed and generally continuous beach ridges.

GLACIAL GEOLOGY IN AMERICA.*

By Herman L. Fairchild Rochester, N. Y.

INTRODUCTION.

The life of this Association, with that of its predecessor, covers precisely the period since the glacial theory was introduced to American geologists. It seems highly appropriate, upon the occasion of the jubilee meeting of this society, to review briefly the history and growth of glacial geology in America and to give credit to the men who were pioneers or who have been most influential in the development of this young and vigorous branch of earth-study.

In the limits of this paper it is impossible to call the roll of

*Vice-presidential address. Section of Geology and Geography. A. A. A. S., Aug., 1898.

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all the investigators in American glaciology,and apology is here offered for many omissions and possible errors.*

THE GLACIAL THEORY.

Announcement. —The "drift" of the northern United States and Canada was not neglected by the self-taught geologists of the early part of this century. Frequent references occur in the writings of those years to the striæ and polished rocks, the stony clay, the deposits of sand and gravel and particularly to the conspicuous erratics and perched boulders. These phenomena were commonly attributed to the agency of violent floods, and were called "diluvial." They were, however, so unlike any products of observable aqueous action that the conditions of their formation were a subject of imagination rather than of scientific inquiry. But this conception of water as the chief or only agent concerned in the production of the drift and striæ gained such general assent and so bound the minds of the older American geologists that the glacial theory was not given at first even a respectful hearing, and it was not accepted until long after a majority of foreign geologists had adopted it for western Europe and the British Islands,—not indeed, until a new generation of workers had possession of the field. The story of the introduction, discussion and final acceptance of the glacial theory in America is an entertaining and instructive chapter in the history of science.

The reports of the early state geological surveys, the transactions of learned societies and the volumes of Silliman's Journal down to about 1850 contain frequent references to "diluvial drift," "diluvial scratches," "tremendous currents of water," and terms of similar import. The first suggestion of ice as a contributory agent in the genesis of the drift, in the form of icebergs or icefloes, was made by Peter Dobson of Connecticut, in a letter to Silliman,† dated November 21, 1825. Mur-

*The writer hopes to insert in the record of Section E for the next meeting (1899) a notice of any important additions or corrections which are brought to his attention.

†It is not desirable to encumber these pages with a great number of bibliographic references. These can be found in chronologic order under authors' names in United States Geological Survey Bulletin No. 127—"Catalogue and Index of Contributions to North American Geology, 1732-1891," by N. H. Darton. (See "Glaciology," page 417 and "Pleistocene," page 756.) Bulletins Nos. 130 and 135 contain the bibliography from 1891 to the close of 1895.

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chison gives to this letter of Dobson the credit of suggesting to him the iceberg hypothesis, while Edward Hitchcock obtained his similar idea from Sir James Hall of Scotland.

So far as the writer has discovered in print no American geologist suggested land or glacier ice as a possible cause of the drift phenomena until 1837. when T. A. Conrad asserted his belief in such agency in the following words:

"Whence then this immense body of ice which has scattered boulders over so vast a tract of country, appearing too at an epoch subsequent to the extinction of the Mastodon and other mammalia, which evidently lived in this region and enjoyed equatorial climate anterior to the icy period? Nothing can reconcile this apparent contradiction but the admission of a fall of temperature far below that which prevails in our day, freezing the enormous lakes of that period and converting them into immense glaciers, which probably continued undiminished during a long series of years."

We cannot, however, regard Conrad's suggestion as a fair presentation of the glacial theory. It was made only incidentally, as an argument for his hypothesis of epochs of cold climate, and without any attempt to give a full statement or to marshall the facts as bearing upon the genesis of the drift. It is significant, however, as indicating, by the casual way in which he introduces the argument, that the conception of great bodies of land ice might not have been, even at that time, an entirely new idea to American geologists. The work which then had been prosecuted for some years upon the alpine glaciers was probably not entirely unnoticed by Americans.

The American geologist who first gave a favorable reception to the glacial theory of Agassiz, as far as printed records show, was Edward Hitchcock. In his address as retiring president at the second annual meeting of the Association of American Geologists and Naturalists, held at Philadelphia, April, 1841, he described the characters of the drift and the various phenomena which we now call glacial with great accuracy and appreciation. After discussing several hypotheses of the drift he writes as follows:

"But the recent work of Agassiz, entitled 'Etudes sur les Glaciers,' gives a new aspect to the subject. Henceforth, however, glacial action must form an important chapter in geology. While reading this work and the abstracts of some papers by Agassiz, Buckland and Lyell, on the evidence of ancient glaciers in Scotland and

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England, I seemed to be acquiring *a new geological sense;* and I now look upon our smoothed and striated rocks, our accumulations of gravel, and the *tout ensemble* of diluvial phenomena with new eyes."

" I do not mention these difficulties (to which I might add more) as any strong evidence against this theory. For so remarkably does it solve most of the phenomena of diluvial action, that I am constrained to believe its fundamental principles to be founded in truth."

In the application of the hypothesis to American drift he stated his chief difficulties to be: (1) the general southerly direction of the striæ and drift transportation over New England and New York, instead of radiating from the highlands as in the Alps; (2) the lifting of the erratics from lower to higher levels, although for this work he regarded ice as more efficient than water; and (3) the localized drift masses which we now call "drumlins." At that time, with only Alpine glacier phenomena as the foundation of the theory, these were valid and forcible objections. Indeed his presentation of the argument for and against glacial agency showed excellent appreciation and grasp of the subject, and to-day can be read with profit. This is also true of his "Postscript," discussing the glacier hypothesis and moraines in the introduction to his Geology of Massachusetts, 1841.

In these writings Professor Hitchcock seemed to declare his adherence to the glacial hypothesis, as applied to America, with as little hesitation and qualification as would be expected of a careful man of science in espousing a new theory that antagonized the prevailing belief and prejudice of his fellow workers. It is evident from subsequent records that his utterances were accepted at the time as committing him to the acceptance of the theory of Agassiz. But, unfortunately for truth and for American geology, the circumstances and scientific forces of that time did not allow him to stand upon the advanced ground he had taken. He was criticised by Murchison, to whom he was attached, and evidently found no support among his confrères at home. Instead of following Buckland in support of the glacial theory he went over to the side of Murchison and Lyell, and the next year at the Boston meeting his elaborate paper on the drift favored the iceberg hypothesis. In 1843 he is quoted in the following words:

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"Professor Hitchcock remarked that so disastrous had been his experience in respect to the glacial theory of Agassiz that he was almost afraid to say anything more on the subject. He had been supposed to be an advocate for the unmodified glacial theory. But if he could trust his own consciousness he had never been a believer in it. By this term (glacio-aqueous) he meant to say that the phenomena of drift were the result of joint action of ice and water, without saying which of these agents had exerted the greatest influence. But whether that glacio-aqueous action had been the result of the enormous accumulation of glaciers, according to Agassiz, or from floating icebergs according to Lyell and Murchison, or of the upheaval of the Arctic ocean whereby its aqueo-glacial contents were precipitated southward according to De la Beche, he had not then made up his mind nor has he yet made it up."

Professor Hitchcock's attempt to find some compromise between the glacial and iceberg theories of the drift was a failure. He came very near to being a glacialist. If he had followed his own perception of the truth he would have been the leader in a great forward movement in geological science, which, by his defection at the critical moment, was suppressed for twenty years.

Discussion.—The printed accounts of the annual meetings of the Association of American Geologists and Naturalists give evidence of a lively interest in the subject of the drift, but there seems to have been no champion of the discredited glacial hypothesis; or if so he was not thought worthy of record. There was much difference of opinion as to the agencies of the drift but all were hostile to the new theory. The brothers Rogers, with Emmons, Jackson, Nicollet, Redfield, Couthuoy and others, lost no opportunity of upholding some form of the diluvial hypothesis and for ten years no American geologist ventured openly to adopt and proclaim the theory of Agassiz. Doubtless there were various reasons for this unreceptive attitude, some of which we can discover. Lyell came to America in 1841, and in 1842 he attended the third meeting of the geologists, held at Boston, and brought the reinforcement of his great reputation to those who favored the hypothesis of submergence and icebergs, of which he and Murchison were the great apostles. The supporters of this theory probably did not clearly understand the genesis of icebergs and did not realize that their hypothesis simply pushed the glacier area some distance northward. The scientific ob-

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jections to the glacial origin of the drift were to them conclusive. They were unable to apply to the broad plateaus of northeastern America the work of local or alpine glaciers. How could ice flow up hill? The glaciers of the Alps all moved down the slopes. How could an ice mass move over even comparatively level tracts? Indeed, Dana did not answer this difficulty until the 1879 edition of his Manual. The prevailing southerly direction of the drift movement, with only minor deflections by mountain masses or great valleys, did not harmonize with conceptions derived from written descriptions of the glaciers of the Alps, and they were not prepared to grasp Agassiz's idea of a great circumpolar ice sheet. The very large proportion of water-worn or water-laid materials in the drift certainly favored aqueous agency.

But there were other antagonistic forces which were not of a scientific character. Agassiz was a comparative young man and quite unknown in geology except for his study of glaciers. How could his opinion weigh against those of the giants in geology? Another power, which will scarcely appear in the scientific writings of the time, but which was a great conservative force, was theological opinion. All hypotheses invoking water as the drift agency might be harmonized with belief in the Noachian deluge, but the Bible gave no countenance to an ice deluge. The "diluvium" was an ever present evidence of the truth of the deluge. To explain it away was little better than heresy. In these days of liberty of thought it is not possible for us to realize the repressive power of religious opinion in Puritan New England. Furthermore the diluvial hypotheses were unduly deductive, and like all opinions not based on observational or inductive evidence did not readily yield to the arguments derived from facts. The older geologists had made up their minds and that settled it. They were also mostly committed in print to some form of the diluvial idea. Those early classics in American geology, the state reports of New York, Massachusetts and New Hampshire, appeared during the years 1841-1844, and by generally referring the drift to aqueous origin helped to fix opinion along diluvial lines. Before leaving this subject it will be well to state briefly the nature of some of the theories of the drift.

Edward Hitchcock had written the Geology of Massachu-

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setts before he became fully acquainted with the theory of Agassiz. He presents the several hypotheses for the drift, but rules out glaciers, retains the term "diluvium," and favors the idea of waves of translation from the arctic region. He displays, however, the openness of mind and keen perception which led him virtually to adopt the glacial theory upon its first fair presentation, by distinctly saying that no theory proposed at that time was satisfactory to him. His "Postscript," describing glacial phenomena, at the beginning of the volume was an afterthought, dated 1841.

Lardner Vanuxem in his Geology of the Third New York District, 1842, referred briefly to the drift, compared the iceberg and glacial theories and gave preference to the latter in some modified form, suggesting the term "local ice" for "glaciers."

In the same year Ebenezer Emmons published the Geology of the Second New York District. He regarded the iceberg theory as fully established. The rock scorings and finer drift he thought were produced by broad shallow currents or rivers, at an earlier epoch, while during a later marine submergence the floating ice had transported the erratics and coarser drift. Glaciers were entirely ruled out.

W. W. Mather in the Geology of the First New York District, 1843, gave an exhaustive account of the drift. Regarding the glacial theory he had the objections noted by Hitchcock. He favored currents of water and floating ice, and thought that the greater currents were due to a relatively sudden collapse of the earth's crust, producing accelerated velocity of rotation, and hence quickened oceanic currents.

In the Geology of the Fourth New York District, 1843, James Hall held views similar to Emmons. He had not seen the writings of Agassiz, and probably very few American geologists had at that time, but he could not admit glacial agency as there was no sufficiently elevated land-mass upon the north.

C. T. Jackson, in his Geology of New Hampshire, 1844, quoted M. de Luc against the glacial theory, even as applied to Europe, and regarded its application to America as absurd. He attributed the drift to Arctic waters and ice, they "having been hurled with great violence over the surface of the northern hemisphere."

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In a review of Dr. Jackson's report, T. T. Bouvé wrote as follows:

"In view of all that is known of the movement of diluvium in this country we cannot but regard the glacial theory as wholly inadequate to produce the results met with, and we think with Dr. Jackson that the grooves on the rocks, if produced by glaciers, should radiate from our principal mountain ranges and should be more abundant in their immediate vicinity, while they should be wanting in the level country and over our extended tablelands!"

The most ardent and extreme champion of De la Beche's hypothesis of catastrophic waves or debacles of water was Prof. H. D. Rogers. The following quotation from his presidential address before the fifth meeting of the Association of American Geologists, held at Washington, May, 1844, will give a sufficient idea of this hypothesis. After discussing the drift at great length and reviewing all the explanation that had been proposed, he gives the following as his own views:

"If we will conceive, then, a wide expanse of waters, less perhaps than one thousand feet in depth, dislodged from high northern or circumpolar basin, by a general lifting of that region of perhaps a hundred feet, and an equal subsidence of the country south, and imagine this whole mass converted by earthquake pulsations of the breadth which such undulations have, into a series of stupendous and rapid-moving waves of translation, helped on by the still more rapid flexures of the floor over which they move, and then advert to the shattering power of the tremendous jar of the earthquake, we shall have an agent adequate in every way to produce the results we see, to float the northern ice from its moorings, to rip off, assisted with its aid, the outcrops of the hardest strata, to grind up and strew wide their fragments, to scour down the whole rocky floor, and, gathering energy with resistance, to sweep up the slopes and over the highest mountains."

To us at the present time it would seem as if the mere statement of this hypothesis should have been sufficient for its own refutation. Certainly it was so far-fetched, calling in an agency entirely outside the range of human observation and knowledge, and at the same time denying the competency of an observable agency which was at that time reproducing some of the most important drift phenomena, that it seems unscientific to the last degree. Yet, in 1849, three years after Agassiz had come to America and long after the detailed arguments for glacial agency had been fully and clearly set before American readers, professor Rogers wrote:

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"V. The diluvial hypothesis, as modified by myself, assumes, not the submersion of the land but a series of violent elevatory earthquake movements, in the arctic regions, displacing the arctic waters, with the ice which bound them, and sending these southward, across the northern districts of the continents."

As early as 1842 the facts concerning the geologic work of the Alpine glaciers and the arguments for the glacial theory had been placed before American readers by the republication in Silliman's Journal of an excellent article by Charles Maclaren. And in the next year of an elaborate review in the same journal, of James Forbes' noble book on glaciers left American geologists with no excuse for lack of general knowledge of the glacial theory and its reasonable claims.

Late in 1846 Louis Agassiz arrived in America. In 1847 he explored the White Mountains and found evidence of local glaciers. In 1848 he visited the great lakes and found abundant evidence of continental glaciation. In September of that year he attended the first meeting of this society, at Philadelphia, and described the glacial phenomena about lake Superior, showing the identity of the phenomena in America with those in Europe. To his personal testimony was added that of Arnold Guyot and Edmund Desor, who had been colaborers with him and had also brought their ample experience to bear upon the American field. The reception by the older geologists of this personal and expert evidence was evidently not of such a character as to encourage Agassiz in further presentation of the matter. In his book on lake Superior, published 1850, he wrote in a somewhat sarcastic vein as follows:

"But such is the prejudice of many geologists that those keen faculties of distinction and generalization, that power of superior perception and discrimination, which have led them to make such brilliant discoveries in geology in general, seem to abandon them at once as soon as they look at the erratics."

Agassiz did not present another glacial paper before the Association until 1870, his chief work in the meantime lying in the domain of zoölogy. However, from about 1850 the extreme diluvial notions were either abandoned or presented less agressively.

At the second meeting of this Association, in Cambridge, 1849, there was the usual animated discussion of the drift, following papers by H. D. Rogers and Arnold Guyot. An ex-

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tended paper by the latter described the glacial phenomena in the Alps, and stated that those of the White mountains were similar. The diluvialists still opposed the glacier theory, even to the degree of questioning the Alpine observations of Guyot and Agassiz. James Hall evidently voiced the sentiments of the younger men when he said, as reported in the discussion:

> "In this country there has been a tendency to oppose the glacial theory because it had been applied for the explanation of diluvial phenomena. We ought to be ashamed in this country, he said, to speak with confidence, after so little research, when there had been so much abroad."

From this time there are fewer references to the origin of the drift. A new generation of geologists was taking the place of the older men and they were freer to accept the new ideas while not aggressively attacking the prevailing ones. The writings of the younger men frequently refer to glacial agency as an admitted fact. Among the contributions to glacial geology in those earliest years of the science but very few can be noticed. In 1850 C. B. Adams, at the New Haven meeting of the Association, read a paper on changes of level in North America, in which, adopting the hypothesis of Lyell, he suggested the elevation of northern land as sufficient cause of the ice sheet; also of submergence at the close of the glacial period to account for the undisputed marine deposits. This hypothesis was elaborated by Dana in his presidential address of 1855, and placed upon a working basis by three time divisions: (1) Glacial epoch, with northern elevation of land; (2) Laurentian epoch, of depression; and (3) Terrace epoch, of moderate reëlevation to present altitude. From this time Dana was the leader of the glacial forces and the chief exponent of the theory.

In 1857 Edward Hitchcock published in the Smithsonian Contributions his extended and valuable paper on Surface Geology, treating chiefly of the Connecticut valley. He distinguished local glacial striæ from the general drift striæ, and recognized moraines and other effects of local glaciers. In 1859 C. H. Hitchcock made the same discrimination for New England in general. The Geology of Vermont, published in 1861, while describing phenomena of local glaciers, attributed the common drift to icebergs. In 1863 the report of progress

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of the Geological Survey of Canada from its beginning to that date, contained a chapter on surface geology, written by Robert Bell, which attributed the drift phenomena to ice and fully accepted the glacial theory, even recognizing moraines in the Ottawa valley.

Acceptance. —It will be seen that the acceptance, in America, of the glacial theory was by slow degrees. It involved the displacement of preconceived deductive hypotheses, and was opposed by the modified and not unreasonable theory of submergence and floating ice, held by Murchison and Lyell, which still has some qualified support. During the decade from 1850 to 1860 there was comparatively less discussion of the drift problem. Geologists were readjusting their ideas and taking new bearings. Then followed the years of the war of the Rebellion, when the thought of Americans was turned away from abstract science and even the meetings of this Society were suspended. However, in 1862, the glacial theory received two notable reinforcements. One was, in England, its public adoption by Ramsay and his abandonment of the iceberg theory; the other, in America, the publication of the first edition of Dana's Manual of Geology. In this epoch-making book in geological science the whole problem of the drift was clearly presented. The arguments for and against both the iceberg and glacial theories were stated with a logical conclusion in favor of the latter, allowing the work of icebergs along the continental borders and across deep channels. An unbiased reader could judge for himself of the merits of the two theories but scarcely fail to accept the conclusion of the author. The glacial epoch as a division of Post-Tertiary time was given its place in the geological time series; and the various elements of the glacial problem were placed before student and worker so as to be available as a basis for investigation. The foundation was laid for the construction of glacial geology, but the time was not propitious for its completion.

Following the close of the war, interest was renewed in glaciology, and two papers by Charles Whittelsey, in 1866 and 1867, are worthy of note. In the latter year a masterly paper by Edward Hungerford, before this Association discussed the physical conditions and climate of the glacial per-

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iod. He did not agree with Agassiz's extreme views of great southern extension of a polar ice-cap; and his moderate conclusions are, in general, accepted to-day.

At this opportune time, 1867, when the greatly stimulated thought of the people was turned into peaceful ways, the revised edition of Dana's Manual carried the glacial theory into every college of the land as the evolutionary product of the discussion upon the drift during the fourth of a century. However, the theory still found some opposition, and as late at 1871 Dana said that American geologists were divided on the iceberg and glacial theories, and he deemed it necessary to give further proofs against the former.

When shall we say that glacial geology had its beginning in America? The discussion of the theory began in 1841 with the address of Edward Hitchcock. The acceptance of the theory by any number of Americans could not have been earlier than the personal advocacy by Agassiz and Guyot in 1848 to 1850. In some qualified form the theory was doubtless adopted earlier by a few independent thinkers, as Conrad and Vanuxem. The general acceptance of the theory and the making of it a basis for systematic work and investigation was probably not before 1867.

The periods in the history of drift-study in America may be stated as follows:

Undisputed reign of diluvial hypothesis—to 1841.
Discussion of the glacial hypothesis—1841 to 1848.
Gradual adoption of the glacial theory—1849 to 1866.
Development of glacial geology—1867 to date.

THE ICE BODY.

Centers of Dispersion. —The early views of the unity and simplicity of the ice-cap, following Agassiz's extravagant hypothesis of hemispheres of ice, did not long endure the test of advancing knowledge. The direction of striæ and the trend of peripheral moraines were soon recognized as indicating complexity of growth and of movement. In 1871 Dana argued for multiple centers of radial movement, and he referred the New England glacier to a source between the St. Lawrence and Hudson bay. In 1879 he said there had been no ice-cap involving the whole polar region, and recognized, also, that an inclination of the land surface was not necessary for the

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movement of the ice-body. In 1880 W J McGee expressed the view that the polar regions were never more extensively glaciated than at the present time. Similar views were expressed by H. Carvill Lewis in 1886, who designated two centers of ice accumulation and radiation, on the east and west sides of Hudson Bay, and in 1889 by Robert Bell, the Nestor of Canadian glacialists.

Dr. G. M. Dawson in 1888 recognized a separate confluent ice mass in British Columbia between the Coast and Rocky mountain ranges, and in 1890 he gave names to two ice bodies, Cordilleran for the one in British Columbia, and Laurentian for the eastern one, which he regarded as surrounding Hudson bay. In 1895 J. B. Tyrell restricted the name Laurentian (Laurentide) to the mass east of Hudson bay, and gave the name Keewatin to the body west of Hudson bav. These three centers ("glacial radiants" of Claypole) were adopted by professor Chamberlin in his chapter on North American glaciology in the latest edition of Geikie's "The Great Ice Age." Dr. Dawson thinks the Keewatin and the Laurentian (Labradorian) centers should be regarded as constituting the "Laurentide group," as distinguished from the far-separated Cordilleran mass.

Migration of Maxima.—The first definite suggestion of lack of contemporaneity in the growth and culmination of the glacial centers was made by Robert Chalmers in 1890. From study of till sheets, boulder trains, etc., in the area of contention between adjacent ice centers Dr. Dawson, in 1895, thought there had been a migration of glaciation from the Cordilleran to the Laurentian plateaus; and in 1896 Mr. Tyrell made a further refinement by claiming that the Keewatin glacier center had its maximum later than the Cordilleran and earlier than the Labradorian; and that a fourth center over Greenland is in existence to-day. This theory of migration of maximum accumulation receives encouragement from the results of recent studies of the Alaskan and the Greenland ice sheets. While the Alaskan glaciers are believed to have been waning in later time, the Greenland ice cap has probably increased, at least on the east coast, during several centuries, or since the time of the Norse colonies.

Thickness. —In 1883 J. C. Smock published an article on

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the thickness of the ice over New England and the middle states. Later observations have shown that the thickness of ice was sufficient to bury the highest mountain peaks within the ice field. Explorations of the Greenland ice cap have yielded data concerning the curving slope of the margin of the ice sheet which seem in the hands of Chamberlin and Upham to give a reliable basis for the comparison with ancient ice sheets. Mr. McGee estimated the thickness in northeastern Iowa as "500 feet a few miles from the margin, to an indefinite but not very much greater thickness in the interior of the ice body."

Direction of Flow.—Previous to 1879 W J McGee was able, by the study of topographic forms of the drift in northeastern Iowa, to determine the direction of ice flow without evidence from striæ. It is now recognized that drumlins and eskers are more trustworthy criteria of general direction of ice movement than the glacial striæ, which are more subject to the effect of local causes. Peripheral moraines are demonstrations of the direction of flow at the margin of the ice sheet. By these several criteria it is now demonstrated that the ice movement followed the trend of the larger depressions and valleys. As early as 1863 Dana argued, from direction of striæ, for distinct glacial flow in the Connecticut and Hudson valleys. The very decided localization of movement in the basins of the Laurentian lakes was shown cartographically by Chamberlin in 1877.

Lobing of Margin.—This is closely related to the flow in the longitudinal valleys, and is produced by the concentration or massing of the marginal ice in such depressions. This was also shown by Chamberlin in 1877 in his map of terminal moraines; those of the ice lobes filling the basins of the great lakes having a conspicuously looped, festooned or crescentric character. Further study has emphasized the lobate form of the periphery of the ice sheet, at least during the recessional phase.

Driftless Areas.—The surprising and apparently inexplicable phenomenon of an area unaffected by ice action, but wholly surrounded by glaciated territory, was brought to notice by J. D. Whitney in 1862. Much doubt was felt regarding the nature and even the existence of this driftless area

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until the observations were fully confirmed by the detailed descriptions and illustrations in the elaborated paper by Chamberlin and Salisbury, published in 1886. The explanation is supposedly found to lie in the peculiar relation of ice movement through the basins, the ice being diverted from this area. Until recently this area was thought to be unique but in 1891 professor Salisbury discovered another small driftless area in western Illinois.

Transportation of Drift.—The precise manner in which the ice carried its burden of rock debris has been in question. Mr. Upham has emphasized the amount of englacial drift. He argues that the differential flow of the ice induces ascending currents which lift the basal or subglacial drift into higher planes of the ice body. On the other hand professor Chamberlin claims that the continental ice mass never held any considerable burden of englacial drift except near the base; and he finds support for his position in the essentially basal character of the debris in the Greenland glaciers. The existence of ascending currents in the ordinary flow of the ice sheet is not admitted by most students of glacial physics. The question is of some moment in relation to the manner of accumulation of localized masses of debris, such as drumlins, moraines and eskers.

As a philosophical discussion of the character and work of a local ice-body, the writings of W J McGee upon the glacial phenomena of northeastern Iowa deserve special mention.

GLACIAL PERIOD.

Cause.—The cause of the glacial period remains quite as much a mystery as it was in 1840. A large body of facts has been collected, but it points in different directions. Every person has entire liberty of opinion; most glacialists have no opinion at all upon this subject. Up to 1875 the Lyellian hypothesis of land elevation as a cause of the cold climate and snow accumulation had the majority of adherents. In America this was proposed by C. B. Adams in 1850, and was adopted by Dana in his presidential address of 1855, and was held by him during his life. It has been the consistent teaching of the Manual of Geology. Of preglacial elevation of northern land there is little doubt, but many glacialists find reason for

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thinking that during the latter part of the glacial period the land was lower than at present, and certainly was so at the close.

Croll's "Climate and Time" presented a plausible astronomical hypothesis, the concurrence of variable elements in the relation of the earth to the sun affecting alternately the north and south polar regions. For a time this won large assent, but objections soon multiplied. The secular periods of glaciation apparently required by this hypothesis in preceding geologic time are quite lacking, although glacial drift deposits occur as far back as the Permian. The most serious objection is the absence of glaciation over vast areas of arctic lands, as Alaska and Siberia. Even the physical competency of the astronomic changes has been questioned, and the hypothesis has fallen into neglect as the tendency of late is to concentrate attention on phenomena and more immediate inferences.

A change in the axis of the earth is a suggestion that finds few supporters. A hypothesis of atmospheric change, a variation in the amount of the carbon-dioxide content of the atmosphere, has recently received the support of professor Chamberlin.

The opinion of the majority of geologists may probably be fairly stated by saying that the various elements affecting climate, geographic, atmospheric and astronomic, are thought to be so nicely balanced that a comparatively slight change or maladjustment may produce serious climatic effects.

Time Divisions.—Professor Dana in 1855 proposed the tripartite division of the glacial period, correlating with land oscillation, into (1) the Glacial epoch with high elevation of land; (2) the Laurentian (Champlain), with depression of the land; and (3) a transition epoch, called the Terrace, during which the land rose to its present level and the river terraces were cut by the enlivened streams. This scheme was elaborated in the first edition of his Manual, in 1862, and adhered to with slight changes in all subsequent editions. In the 1879 edition he gave the Terrace epoch a formal place, changing the name in the last edition to "Recent." The name "Champlain," originally given to the marine clays by Edward Hitchcock, was substituted for "Laurentian" in the edition of 1867.

While this terminology has been generally used and the

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time divisions adopted in a general way, some modifications have been thought desirable. It is believed by many that the Champlain subsidence was far along, perhaps at its maximum, before the ice sheet retreated. Indeed, Mr. Upham would make the Champlain only the closing part of the Glacial epoch. The "Recent" epoch is now regarded as essentially a part of the present epoch, and this view is strengthened by the demonstration, by Mr. Gilbert, that the northward differential uplift of at least the Laurentian basin is still in progress.

Interglacial Epochs.—Dana held firmly to the essential unity of the Glacial epoch, and in this he was largely followed, especially by the men who were trained upon the comparatively simple, homogeneous drift sheet of the eastern states. But in the broad areas of the west the drift is not so simple. Early in the study of the region buried soils, peat beds and other evidences of deglaciation were found intercalated in the drift, and were noted by Whittlesby, Newberry, Orton, N. H. Winchell and others. In 1873 Newberry regarded the "Forest Bed" as marking a distinct deglacial condition in the drift period. In 1878 McGee described vegetal deposits in the drift of northeastern Iowa of such depth and areal extent as to indicate an interglacial epoch, and he discriminated a later from an earlier till. Subsequently Chamberlin accepted these conclusions, and in 1882 he discovered the greater southern extension of the older drift and noted the evidences of a long interval between. This idea of the duality or multiplicity of the glacial epochs met with long-continued opposition, but was found by the glacialists of the west a good working hypothesis, and evidences in its favor have multiplied.

In 1889 Chamberlin regarded the fringe in Pennsylvania as the unburied edge of the older drift, and in 1891 Salisbury described the extra-morainic drift of New Jersey and Pennsylvania as the weathered and eroded border of a drift sheet far older than the moraine-bordered till. This was the first recognition in the eastern states of multiple drift phenomena, comparable to that in the western states.

The study was given definiteness and placed on a working basis by the admirable article of professor Salisbury, in 1893, on the "Criteria for recognition of distinct glacial epochs." The application of these criteria by different workers, particu-

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larly Leverett, Coleman and Hershey, has so strongly confirmed the view of distinct ice invasions separated by intervals of deglaciation that this has passed quite beyond the point of argumentation, and the question now is as to the extent and duration of the stages of deglaciation, or the relative length and importance of the glacial and interglacial time divisions.

In 1894, professor Chamberlin presented the whole matter, in condensed form, in Geikie's "The Great Ice Age," and set the example, subsequently followed by Geikie, of denoting the several glacial time divisions by geographic names, using the names of areas where the individual deposits are typical. In 1895 he gave similar names to the interglacial epochs. The contemporaneity in Europe and America of the climatic oscillations and the epeirogenic movements, at least in a general way, seems quite demonstrated by the studies of Chamberlin and Geikie.

Time Subsequent.—A question of great popular interest concerning glaciation is that of time,—the time in years, especially since the ice disappeared. Glacialists will in honesty have to admit that they cannot yet fully satisfy that proper curiosity. That the time is very brief, judged by geologic time standards, since the ice sheet finally disappeared from our region, seems certain. Judging from the freshness of the glacial scorings and the deposits, 5,000 or 10,000 or 15,000 years is thought by many glacialists to be a fair estimate of the length of their exposure. But no reliable chronometer has yet been found. Niagara gorge has been regarded as the best timepiece, but fuller study has made the "Niagara Problem" more complex and uncertain. It seems likely that the volume of Niagara's water has varied greatly for long periods, as the history of the river is intimately connected with that of the glacial lakes of the upper lake basins. It is admitted that during the ice retreat the Laurentian basin was lower, as regards sea level, than at present; and was progressively lower northward and northeastward. It also seems certain that at the time of the ice removal the waters found lower outlets eastward from lake Huron than by way of lake Erie, and that such outflow persisted until the slow differential uplift raised the northern outlet above the St. Clair outlet. Hence for one, or probably two, long stages Niagara river carried only the

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insignificant drainage of the Erie basin. This argues for greater length of postglacial time. On the other hand there is a question as to the origin of the gorge, whether cut *de novo*, or in part reëxcavated or enlarged by the modern river. The chief students of the subject have been Gilbert, Spencer, Upham and Taylor. Out of the mass of literature two papers must be noticed: that of Gilbert, "The History of Niagara River," 1890, which placed the elements of the problem before the public; and the paper by F. B. Taylor, 1898, "Origin of the Gorge of the Whirlpool Rapids at Niagara," which gives the latest results of the correlation study of Niagara and the glacial lakes.

The recession of St. Anthony's Falls in the Mississippi has also been studied as a measuring rod of postglacial time, especially by N. H. Winchell, with results concordant with those of Niagara and other similar studies.

Recently Mr. H. M. Bannister has argued for great duration of the ice sheet, from data derived from transportation of far-travelled erratics; and Mr. Taylor finds a great length of time required to form the moraines of recession in the Erie-Huron basin laid down by the slow oscillations of the ice front; the latter paper favoring astronomical forces as a cause of glaciation, at least in part.

The question of glacial time is closely connected with the problem of glacial cause.

INTERPRETATION OF SPECIAL PHENOMENA.

Drumlins.—These are usually conspicuous topographic features and frequent references to them, under various descriptive terms, occur in the early literature of the drift. Under the diluvial hypothesis little effort was made to explain their origin, and Edward Hitchcock found in them an objection to the glacial theory.

The name "drumlin" was applied in 1866 to similar drift masses in Ireland by H. M. Close. In America various appellations were given: by professor Shaler, who was the first American to write upon them,—"drums" and "sow-backs," 1870; by C. H. Hitchcock, "lenticular hills," 1876. The elongated forms of central New York were described in 1882 by Laurence Johnson as "parallel drift hills," and professor

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Chamberlin in 1883 called them "mammillary" or "elliptical hills." The name drumlin was proposed for use in this country by W. M. Davis, in 1884, and at once adopted.

As nearly all drumlins are composed wholly of till, and especially so in the superficial part, it was early recognized that they were an immediate product of ice work, and they were so referred by Close as early as 1864. In 1872 Kinahan and Close regarded them as subglacial and constructive, comparing them to the longitudinal sand-bars in the bed of a stream. This view of the genesis of drumlins has been adopted, in a general way, by most American glacialists. The suggestion, made by professor Shaler in 1870, that they may be remnants of an earlier, eroded drift sheet, or that they represent old moraines remodelled by readvance of ice, as proposed by C. H. Hitchcock, have been quite abandoned. Their parallelism with the direction of ice movement was first noted in America by Hitchcock and Upham in 1875. In 1883 professor Chamberlin discriminated drumlins from moraines, as being longitudinal, or axi-radiant with reference to the moving ice body.

The hypothesis of drumlin origin by the piling of the ground-moraine by differential pressure and movement of the overriding ice body, along the peripheral zone where transporting power becomes inadequate to the drift burden, is regarded as a plausible and satisfactory explanation. The chief objection to this is negative, the failure of more uniform distribution and even the entire absence of drumlins over vast areas of drift. Another difficulty is physical; a lack of precise knowledge of the manner in which ground moraine is lifted in relatively short distances to heights of 100 or 200 feet. Mr. Upham has attempted to solve this problem by an argument for the construction of drumlins, and moraines also, by the lodgment of englacial drift. This difficulty is less acute, however, since professor Chamberlin had observed sections of miniature drumlins beneath the ice foot of the Greenland glaciers, with the overriding ice moulding itself to the drumlinoid curve.

Moraines.—The masses of moraine drift were not entirely overlooked in early writings upon the diluvial phenomena, yet they were not emphasized since their superior importance and

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interest only appear with their recognition as marginal phenomena of the ice sheet. On account of their irregular topography and areal distribution they are not so likely to attract attention as drumlins or even as some eskers, and not until the glacier theory was so established as to be made the basis of observation and investigation were moraines discriminated and mapped. Their systematic study is within the last twenty-five years.

The earliest mention of moraines, by that name, in American geology is believed to occur in the postscript to Edward Hitchcock's Geology of Massachusetts. (See above, page 160.) Appreciating their significance as glacial phenomena he gives a large space to moraines and notes their occurrence at various localities. The closing paragraph is as follows:

> "It is possible that the whole of cape Cod is nothing but a vast terminal moraine, produced by a glacier advancing through Massachusetts bay and scooping out the materials that now form the cape? In this case the moraines at Plymouth and Truro would form part of the lateral moraines, and probably most of Nantucket and Martha's Vineyard might be regarded as moraines of the same glacier, when it extended further south."

The hills of the Long island moraine were described by Mather in 1843, in his report on the first New York district, but without recognizing their true character.

In his chapter on surface geology, in the report on the geological survey of Canada for 1863, Robert Bell described ridges of drift as resembling moraines, along the Ottawa river, which was a correct diagnosis. His map of superficial deposits, accompanying that report, is believed to be the first map of Pleistocene deposits published in America with recognition of glacial agency.

In 1864 J. D. Whitney published a notice of terminal moraines of alpine glaciers in the Sierra Nevada, about Mt. Lyell and Mt. Dana. In 1866 Whittlesey indicated on his map, in the Smithsonian Contributions, "morainic knolls" south of lake Erie, also west of lake Michigan, the latter being the noted "kettle range," studied later by Chamberlin, but apparently he did not understand their significance as terminal drift.

In his report of the Iowa geological survey, 1870, Dr. C. A. White refers certain ridges, somewhat hesitatingly, to ter-

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minal moraines. Excluding the references by Edward Hitchcock, this is probably the earliest notice printed in the United States of terminal moraines in the open country, as distinguished from those of alpine glaciers in the mountain valleys.

In 1871 Mr. Gilbert described the series of recessional moraines in the Maumee valley; and from this time the study of morainal drift was prosecuted with more confidence.

Probably the earliest positive recognition of the great terminal moraine of the continental ice sheet was made by C. H. Hitchcock in a paper on the Long island moraine read before the New York Lyceum of Natural History in 1868, but never printed. Several years passed before there were any published descriptions of the terminal moraine, and it is interesting to note the comparative suddenness and contemporaneity with which several workers covered the entire line of terminal drift from Cape Cod to the Missouri. In 1875 G. M. Dawson recognized the "Missouri Coteau" as marginal glacial debris. In 1877 T. C. Chamberlin described the Wisconsin kettle moraine and indicated the southern limit of drift from Nebraska to New York. This was the first definite mapping of moraines in American geology. In the same year George H. Cook and John C. Smock published their first paper on the terminal moraine crossing New Jersey, and in 1878 and 1879 Warren Upham published descriptions of the terminal moraine series which he had surveyed from Staten island to cape Cod. In 1881 H. Carvill Lewis and G. F. Wright traced the same drift series across Pennsylvania, the results being printed in 1884. Professor Chamberlin's classic paper on the "Terminal Moraine of the Second Glacial Epoch" which has been a basal reference for all subsequent work upon the moraines about the great lakes, was published in 1883. It will be seen that within six years, 1877 to 1883, the important terminal and recessional moraines within the limits of the United States were located and described; and although the work in preparation for publication, especially by professor Chamberlin, must have occupied some years preceding, it is nevertheless a good example of the saltant character of intellectual progress.

In 1878 professor Chamberlin correlated the cape Cod-Long island morainal series with the "kettle moraine" belt of the interior region.

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A discrimination between the extreme southern tract of the drift, in the Mississippi basin, and the more definite morainal belt of a later ice invasion was made by professor Chamberlin in 1882. A similar discrimination in Pennsylvania and New Jersey was made by R. D. Salisbury in 1891.

Against the great debt which American glaciology owes to European investigation there is something on the credit side. The skill acquired in the study of American moraines enabled two American geologists to find similar phenomena in Europe. H. Carvill Lewis, in 1886, traced terminal moraines in Great Britain and Ireland, and one year later R. D. Salisbury did the same thing in Germany, these being the first discovery of open-country moraines of the massive order of the European ice sheets. These discoveries of European peripheral moraines were of great importance, as they laid the foundation for further location of morainal belts and so made possible a comparison of the marginal oscillations of the ice sheets of the two continents, by help of which the geologic equivalency of the successive glacial and interglacial deposits of Europe and America has been determined.

A peculiarity of the American deposits is the peripheral moraines common to, and produced by, two opposing or adjacent ice lobes and termed "interlobate" by professor Chamberlin.

The correlation of moraines of recession with glacial lake shorelines will be noted below. In the study of the successive moraine belts between Cincinnati and Mackinac, F. B. Taylor has reached the conclusion that these moraines were produced by periodic oscillations of climate, so slow as to be referable only to some astronomical cause, probably the precession of the equinoxes. But Croll's hypothesis is not believed to furnish alone a satisfactory explanation.

As regards the precise manner of morainal accumulation, especially of the taller hills, there is not entire concordance of opinion. In several writings Mr. Upham has argued that the moraines were formed from englacial drift during episodes of equality of advance and melting, following stages of greater ablation and concentration of superglacial drift; and that these conditions were possible only during the warm Champlain epoch. Other writers deny the existence of any large amount

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of englacial drift, except near the base (see page 168) and regard even the highest moraine hills as due to piling of subglacial or basal drift by the thinner ice edge overriding its own debris.

Eskers.—The name "osar," borrowed from European literature, was applied by Edward Hitchcock to masses of waterlaid drifts as early as 1842, and appears frequently in subsequent writings upon the drift. The word was generally used without close discrimination, however, being applied to irregular mounds of gravel and sand as well as to ridges. An early identification was made by C. T. Jackson, in 1843, who said that the European osars were identical with the "horsebacks" of Maine. During subsequent years down to 1880 the word "kame" was generally employed instead of osar. The name "serpent kame" was applied by Shaler in 1888, in print.

The term "esker" was first used by G. H. Kinahan in 1863, being applied to gravel ridges in Ireland, but in America it remained for W J McGee to make, in 1881, the needed differentiation between eskers, applied to elongated ridges of gravel and sand, and kames, designating sand or gravel deposits of irregular or morainic topography. Gradually the word esker has displaced the less convenient word osar, although the latter has priority.

Since the acceptance of the glacial theory it has generally been recognized that these ridges of gravel, under whatever name, were formed by glacial streams. In 1872 N. H. Winchell attributed the gravel ridges observed by him in Ohio and Minnesota to the work of streams in longitudinal crevasses, and a more definite explanation in America was made by Warren Upham in 1876, when he referred those in New Hampshire to glacial rivers, either supraglacial or subglacial.

The genetic distinction between eskers and kames, made by McGee in 1881, was emphasized and amplified by Chamberlin in 1883 and 1884, referring the esker phenomena (using the term osar) to the class of axi-radiant or longitudinal stream drift, as distinguished from the peripheral kame deposits. That eskers are constructive forms, deposited in the beds of glacial streams, in comparatively stagnant ice, seems to be universally admitted. There remains, however, some lack of unanimity as to the attitude of the streams, whether

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upon or within or beneath the ice body. In 1884 professor Shaler gave reasons for believing them to be formed in channels of subglacial streams. Mr. Upham has regarded the streams as superglacial after the subglacial channels had become obstructed, or in some cases as flowing in deep ice-walled canyons, reaching perhaps to the ground. Down to 1890 George H. Stone, in his writings upon the drift phenomena of Maine, regarded the esker streams as mainly superglacial, but in 1893 he thought them subglacial, at least in the coastal region. In a critical study of the origin of certain eskers in Massachusetts by W. M. Davis, and in a discussion of the mechanics of the phenomena by J. B. Woodworth, both authors conclude that the streams were subglacial; and the weight of opinion now favors subglacial streams in the relatively stagnant submarginal portions of the ice sheet. The observations of professor Russell in Alaska and of professor Chamberlin upon the ice foot in Greenland, give force to this view. There seems to be no better explanation for the greatly extended, continuous eskers of uniform cross section, or prism, which traverse hills and valleys, than that they were formed in tunnels in or beneath the ice; the streams in many cases being under hydraulic pressure. But doubtless some of the broader or shorter, discontinuous, irregular ridges may have been deposited in other ways, near the ice front. A question of some importance in this connection is the relative amount of interglacial or superglacial drift. In an ice body with little debris above its base only subglacial streams could acquire great burden.

In northeastern Iowa occur some unique deposits which may be regarded as allies to eskers. They have been described by McGee and named "paha." These are elongated ridges of aqueo-glacial material upon the surface, deposited in canyons in the ice. "The streams were originally superglacial, so that the modern drainage is 'superimposed from ice,' to use Gilbert's expression; these streams were originally located by eminences under the ice, which retarded the flow and developed incipient lobation; and after the streams had deepened their channels so far as to materially reduce the thickness of the ice, then the subglacial water was forced toward the same lines, and the superglacial and subglacial flow

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coincided and eventually formed ice canyons in which the paha were accumulated."

Kames.—In an historical way it is difficult to discuss kames apart from eskers, as in the literature down to 1881 the several names employed were used quite indifferently and the two forms of deposits were not discriminated.

Edward Hitchcock in 1847 evidently described areas of kames under the name of "moraine terrace," and admitted that he was unable to determine their origin.

As stated above (see under eskers) the name was first used discriminatively by McGee in 1881, and Chamberlin in 1883 and 1884 described them as constructional forms, not erosional, as some writers had thought, and grouped them genetically with water-laid drift, peripheral to the ice body and associated with terminal moraines.

As to the precise physical conditions under which kames, kame-areas and kame-moraines were formed there is still some uncertainty. That they were deposited by glacial streams in immediate relation to the ice edge is regarded as quite certain. But were they formed on open ground, or in standing waters? And were they from subglacial drainage or from streams higher in the ice sheet? The latter question is partly dependent upon the amount of interglacial and superglacial debris. Mr. Upham has favored the latter source of supply, but from the study of the Greenland glaciers Chamberlin thinks that both kames and eskers are from basal drift, and are "products of relatively active, vigorous glaciers." It seems that the existing glaciers of Alaska and Greenland suggest subglacial origin of the kame drift, but it is conceivable that the conditions of the American continental ice sheet may have been different.

In 1884 professor Shaler presented an argument for the formation of kames in static water by detritus-burdened subglacial streams issuing from the ice front under hydraulic pressure. This theory might explain the majority of kame deposits, which with highly accentuated topography, seem more abundant in localities of marine or lacustrine submergence during the ice recession. But mounds of water-laid drift are found at various altitudes and such were evidently formed under different conditions. It might be well to dis-

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criminate here and restrict the word kame to the typical subaqueous deposits and find another term for the subaërial accumulations.

Kettles.—Perhaps less progress has been made in explanation of the hollows or bowls called "Kettles" than of any other glacial phenomenon. The explanation of their origin made by Edward Hitchcock in 1841, that they were produced by the melting of buried masses of ice, is still the common interpretation of their genesis. In 1859 this idea was adopted by Whittlesey in his paper on the "Drift Cavities or Potash Kettles of Wisconsin." In 1877 professor Chamberlin mentioned four possible causes of Kettles: (1) irregularities of heaping; (2) the pushing of one drift ridge unconformably against a preceding one; (3) the incorporation of ice blocks; and (4) under-drainage. In 1884 Dana thought the basins in the gravel terraces of the New Haven region were produced by eddies in the flowing water; but these have been examined by J. B. Woodworth who pronounces them typical ice-block kettles. Those irregular depressions, sometimes of large size, which occur in water-laid drift, suggesting the name "pitted plains," have received no other acceptable explanation than that of ice-block genesis, although still regarded by many geologists as of uncertain origin.

It seems probable that "kettles" may be of various origin. Some of those in moraine and kame deposits may be due to irregular piling of the drift, while others were most certainly occupied by ice blocks during the deposition of the drift. Some of those in delta terraces are evidently due to deficient filling by the capricious action of shore and stream currents. The larger and deeper ones in river terraces or in deltas, giving rise to the name "pitted plains" are most probably of ice block origin.

The literature of the subject is scanty. Among later writers are Mr. Upham and professor Woodworth. The latter has endeavored to estimate the size of the ice blocks from a study of the kettles.

Valley Drift, Terraces.—The enormous quantity of water-laid drift in the stream valleys leading south from the glaciated areas, as well as within those areas, was the firmest basis for the diluvial hypothesis of the drift; and the early literature

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contains considerable matter upon the subject. Down to 1857 the most voluminous writer was Edward Hitchcock. As early as 1833 he explained the Connecticut river terraces by a down-cutting of the river through beds deposited in higher stages of flood. In his paper of 1857 he recognized the complexity of forces and thought that the valley terraces were formed in different ways; those of the Connecticut valley chiefly by a slow lifting of the land with local changes or shifting of the streams. The recognition of the valley drift of New England as derived from glacial debris and deposited by glacial floods was made by Dana in 1855. As early as 1858 M. Tuomey suggested that the Mississippi valley drift was deposited by floods from the sudden melting of the northern glaciers, and in 1859 E. B. Andrews correlated the terraces of the southern Ohio valley with the glacial drift.

Concerning details of the terrace formation in New England there have been divergence and changes of opinion. In the earlier editions of his Manual Dana held that the terrace drift was accumulated during a time of land depression and slack drainage, and the terraces excavated during pauses in the reëlevation of the land. But in the edition of 1879 he admitted that the height of the upper terraces marked the height of the glacial flood, and that change of land altitude was not essential; thus granting the early contention of Hitchcock.

Loess.—The resemblance of certain superficial deposits throughout the interior portions of the United States to the "Loess" of Germany and of China was recognized early in this century, but the writer is not certain of the earliest suggestion of connection of the deposit with glacial phenomena. Such suggestion was made as early, at least, as 1866, by Whittlesey, who attributed the "loess-like" deposits of Illinois, southern Iowa and Missouri to floods from the melting ice sheet. From that date to the present the numerous writers upon the loess have been almost unanimous in regarding the American deposits as aqueous, and as having some relation to glacial conditions, although there were differences of opinion as to the precise conditions of deposition. One notable exception to this view was published in 1879 by R. Pumpelly advocating the eolian origin of much of the Mississippian loess. A paper by J. E. Todd before this association in 1878

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gave a good summary of the aqueous argument. In 1881 Chamberlain was almost alone in thinking that the loess of Iowa and Nebraska was partially aqueo-glacial and partially eolian, in which opinion others now concur.

During the years 1878-1881 McGee discovered that the Iowan loess was an aqueo-glacial deposit, marginal to the drift sheet now named "Iowan." This work was published in 1882. This idea was subsequently amplified and given with more fullness and detail by Chamberlin.

The description by Todd and Bain, in 1895, of six feet of till, supposed to be of iceberg origin, intercalated in the loess of Iowa, would help to confirm the theory of fluvio-lacustrine origin of at least those deposits.

The latest conclusions upon the subject of the loess are found in two papers of last year, one by J. A. Udden, the other by Professor Chamberlin, which agree in attributing the Mississippian loess partially to eolian origin. The paper of Mr. Udden argues for the atmospheric origin in larger part. Professor Chamberlin holds that the loess was originally glacio-aqueous and only secondarily eolian, the latter in minor part; in these respects differing from the Asian loess of Richthofen.

Lake Basins.—Preglacial Drainage.—The problem of the origin of lake basins, especially those of the Laurentian system, has been so intimately connected with glacial studies that the subject should be mentioned.

With the extreme views of glacial erosion that were current after the general adoption of the glacial theory of Agassiz it was but natural to attribute even larger lake basins to the gouging erosion of the ice sheet. That such is the genesis of many smaller tarns and lakelets in areas of thin drift is admitted. Geikie states this emphatically for Scotland, and Bell for Canada. Twenty years ago Newberry so explained the great lake basins, with Dana assenting somewhat cautiously. As late as 1894 professor Tarr thought that the Cayuga basin had been deepened 450 feet by glacial erosion.

On account of the incidental character of the references to this matter it is doubtful where credit should be given for the earlier suggestions of the current views. As early as 1866 Whittlesey recognized that the preglacial topography of the region of the great lakes was in its broader features the same

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as at present. This was an important observation and gave a basis for moderate views. In 1881 J. W. Spencer attributed the great lake basins to subaërial and fluviatile agencies, and professor Claypole the same. The complexity of their origin was emphasized by professor Chamberlin in 1883, and this now seems evident.

In 1863 J. P. Lesley attributed the New York lakes, with Erie and Huron, to "northward rise of their floor-rock." This keen inference has been verified by studies of the old shorelines. It is now generally believed that the great lakes occupy preglacial basins of subaërial erosion, modified in some unimportant degree by the mechanical abrasion of the ice; and that the ponding of the water, while possibly due in some extent to morainal damming, is chiefly due to differential northeastward uplift.

Dr. Newberry, as early as 1862, showed the existence of ancient river channels in the Erie basin buried under glacial debris, and proving the higher altitude of the land in preglacial time. In 1869 he predicated the existence of an undiscovered channel that must have been the preglacial connection of the Huron and Erie basins, and in many subsequent writings he discussed the ancient drainage of North America. Dr. J. W. Spencer subsequently took up this work in the Laurentian basin with good results, and has endeavored to map the preglacial drainage of the great lakes.

The studies of Spencer, Carll, Foshay, I. C. White, Salisbury, Chamberlin, Leverett and others, indicate that some of the area, now drained southward by the upper Mississippi, Ohio and Susquehanna, was in preglacial time probably drained northward.

Glacial Lakes.—The glacial phenomena receiving the latest serious study are those of ice-dammed water. The subject has been found of unusual and romantic interest and considerable literature has accumulated, chiefly during the last decade.

The necessary existence of lakelets or small ephemeral bodies of water between the ice foot and north-sloping land surfaces has long been recognized, but it is only in recent years that the conception has been enlarged to grasp lakes of vast extent and duration. The possibility of such lakes has been

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questioned, but the facts are so numerous, so easily found and verified and so clear and incontrovertible that doubt is no longer possible.

With the approximate determination of the trend of the retreating ice foot, as shown by the peripheral drift, the history of the glacial waters becomes possible. The study of glacial lakes naturally followed the study of moraines. The two studies are now prosecuted together with advantage, since it is found that shorelines and outlet channels must frequently correlate with moraines.

The conspicuous shoreline phenomena about the Laurentian great lakes were early observed by settlers and travellers, particularly in the basins of Ontario and Erie, and their character as beaches was understood. Lyell in 1842 regarded them as marine, but the common explanation and the correct one, attributed them to fresh waters. They were the subject of study and printed description by Thomas Roy (1837), Lyell, Hall, Whittlesey, Newberry, Gilbert, N. H. Winchell and Klippert before the true cause of the high waters was understood. Dr. Newberry seems to have been the first one to recognize the ice barrier as the occasion of the high-level waters in the Laurentian basin. As early as 1862 he clearly described the ice wall of the retreating glacier as forming the northern shore of the fresh-water inland sea and described the consequent phenomena. In 1869 he presented the same facts more definitely and with greater fullness, but apparently he did not yet clearly realize that the ice wall was the dam or barrier which retained the broad waters at the ancient high level, suggesting, instead, some change in the attitude of the land. However, he did recognize the ice barrier in his first volume on the geology of Ohio, published in 1873; and in the second volume, 1874, he not only clearly predicated the ice dam but discussed the whole history of the glacial waters, from the early primitive stages, in a manner that shows he had a clear conception of the main facts.

Before this association in 1872, N. H. Winchell suggested the damming of the Michigan waters upon the north as having made the ancient Chicago outlet effective; also the blockade of the St. Lawrence valley as causing the high-level waters in the Erie basin. The latter suggestion doubtless implied the

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blocking also of the low divide between the Ontario basin and Mohawk valley, which is far below the old shorelines. In the same year, 1872, Winchell suggested that the waters of the Winnipeg basin (lake Agassiz) had been forced south, through river Warren, by a glacier barrier. These were probably the earliest definite localization of glacial waters.

The first mapping of ancient beaches, and the correlation of those beaches with an abandoned outlet, was by Mr. Gilbert, in 1871, in description of the Maumee valley beaches and the Fort Wayne outlet. Land deformation he supposed was the cause of the change in water level.

The tracing of the beaches in the Erie basin was done by Gilbert, Winchell, Klippert and Newberry mostly before 1872. Newberry's map of the beaches west of Cleveland, 1874, is the first map of glacial lake beaches, so recognized.

The earliest systematic work upon the beaches in the Ontario basin was done by J. W. Spencer and published in 1882 with a theory of marine origin. In 1885 Mr. Gilbert printed a description of the high beaches upon the southern side of the Ontario basin and correlated them with an eastward outlet by the Mohawk-Hudson. The names Warren, Algonquin and Iroquois were applied by Spencer to the ancient high waters of the Erie-Huron and the Ontario basins in 1888, but with denial of their glacial character.

The earliest comprehensive account of the glacial lake history of the Laurentian basin was published by Gilbert in 1890, with maps, which were the earliest cartographic representation of glacial lakes. In this admirable paper he showed the rise of the beaches northeastward, due to the differential uplift of the region; the fluctuation of level in the basins produced by the opening of successively lower outlets toward the north and the progressive tilting of the land throwing back the flow upon southern outlets; with the final result in the present great lakes.

For the full confirmation of the theory of glacial dams it was necessary to prove the actual relation of moraines, as marking locations of the ice barrier, to the beaches. This was first done by Frank Leverett in 1892, in the western section of the Erie basin; and in 1895 in the southeastern section. In 1896 F. B. Taylor correlated the beaches and moraines in

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southeastern Michigan, thereby finding the key to the glacial lake succession in the Erie-Huron basin. His tracing of subaqueous moraines from highland to highland and the correlation with old outlets and shorelines leave no chance for further doubt of the adequacy of glacier dams.

The largest known glacial lake, and the one most fully described, is lake Agassiz. The shoreline phenomena of this lake were described in part by H. Y. Hind as early as 1859. The southward outlet to the Mississippi was described by G. K. Warren in 1868. The glacial character of the waters was suggested by N. H. Winchell in 1872 and 1877. The name "lake Agassiz" was applied by Warren Upham in 1879, who has immortalized the lake, and himself, by his recent monograph.

Several other investigators have described glacial lake phenomena in different localities: G. H. Cook, in New Jersey, with later description of his "lake Passaic" by R. D. Salisbury and H. B. Kümmel; E. W. Claypole in Ohio; C. R. Dryer, in Indiana; S. P. Baldwin in the Champlain valley; E. H. Williams, Jr., in the upper Lehigh valley; I. C. White in the Monongahela valley; the writer in central-western New York; and especially F. B. Taylor throughout the larger part of the area of the great lakes.

The glacial lake studies have developed interesting and important results concerning crustal movements. The deformation of the shorelines gives values for the epeirogenic differential uplift over the Laurentian and the Winnipeg basins during postglacial time, of which the full significance may not yet be developed. An interesting problem now in process of solution by Taylor, Gilbert and others is the relation of glacial lakes in the upper Laurentian basin to the history of the Niagara river and the excavation of the gorge. (See above, pages 171-172.)

EXISTING GLACIERS.

The existence of living glaciers in the United States has been recognized since about 1870, and it is found that in Oregon and Washington are alpine systems which are in some respects as interesting and instructive as those of Switzerland. The glacier fields of Alaska and adjacent Canada are far superior to those of Europe, and include the only known exam-

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ples of the "piedmont" type, of Russell, the broad and comparatively stagnant field, fed by streams of the alpine type. Excepting the little known and inaccessible Antarctic area, North America possesses, in Greenland, the only existing "continental" glacier.

The first recorded observation of glaciers in the United States was made by members of the Williamson Expedition, in 1855, as Dr. Newberry stated, in writing many years later, that some of his party found miniature glaciers at the heads of streams in the group of Oregon mountains called the Three Sisters; but no description was published. In 1857 Lieut. A. V. Kautz reported the discovery of a living glacier on Mt. Rainier. In 1868 E. T. Coleman explored Mt. Baker and published in the following year a description including the glaciers. The earliest important study made by trained geologists was upon the glaciers of Mts. Shasta, Hood and Rainier in 1870, by Clarence King, S. F. Emmons and Arnold Hague.

The first geologist to examine the Alaskan glaciers was W. P. Blake in 1863, his account being printed in 1867. W. H. Dall and Marcus Baker studied the glaciers of Yukutat bay in 1874 and named the famous Malaspina glacier. Other explorers were John Muir, 1878, who discovered Glacier bay and the glacier subsequently named after him; Dall, the second visit, in 1880; G. F. Wright and S. P. Baldwin in 1886; Lieut. Schwatka and William Libbey in 1886, who gave many names to the glaciers about Yakutat and Icy bays; H. F. Reid and H. P. Cushing in 1890; and I. C. Russell in 1890 and 1891. Professor Russell discriminated and named the "piedmont" type of glacier in 1891, from his study of the Malaspina. The Copper river glaciers were noted by Lieut. H. T. Allen in 1887, and were seen by C. W. Hayes and Lieut. Schwatka in 1891.

The Canadian glaciers were first explored in the Selkirk range by Rev. W. S. Green, in 1888.

The Greenland ice foot has long been seen by voyagers, and has been written upon since 1721. The modern study began with Nordenskiold's first exploration, in 1870, and with Helland's measurements of the ice movement in 1875. The public is familiar with the venturesome trips on the Greenland ice cap by Lieutenant Peary in 1886, 1892, 1894, 1895, and the

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trans-Greenland journey of Nansen in 1886. While adding something to glacial science, the work of these and other explorers was more particularly along lines of geographic and meteorologic science. The close geologic study only began with the work of Chamberlin in 1894. This work has been carried on by Wright, 1894; Salisbury, 1895; Barton and Tarr, 1896.

In accumulating literature upon the living glaciers of the continent the papers by H. F. Reid and I. C. Russell, relating to the physics and phenomena of Alaskan glaciers, deserve special mention, with those of professor Chamberlin descriptive of the structure and behavior of the Greenland ice. Two writings of professor Russell of a general or descriptive character, bring down to date a summary of our knowledge of the glaciers of the continent; the first on "Existing Glaciers of the United States," 1884, and the second a book of the past year, entitled, "Glaciers of North America."

Down to a few years ago our knowledge of glacial physics was almost entirely derived from European study. However, the glaciers of the Alps gave but small or unsatisfactory help toward the explanation of some of the most important phenomena produced by the continental ice sheets, for example, the general sheet of till, drumlins, and the various aqueo-glacial deposits as eskers, kames, loess. The interpretations were largely inferential. More has been learned of the structure, behavior and work of our ancient ice sheets by the study of the Alaskan glaciers during the last ten years, and especially by the study of the Greenland ice cap during the last four years, than by all the study of the Alpine glaciers for the seventy years since they have been observed.

The North American continent is recognized as the theater of the greatest display of glacial activity, not in the past only, but also in the present. It must become the Mecca of the foreign glacialist. Though much has already been accomplished the work in America has only begun, and there is large opportunity for future investigation.

About 1850 the Agassizian hypothesis became the glacial theory. Now the glacial geologists understand that the glacial genesis of the "drift" is no longer a theory but an established fact. They will do well to cease paying the deference to doubt, implied in the word "theory," and abandon its use in

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connection with the casual relation of the glacial phenomena. The glacial drift is as much a scientific fact as the volcanic cone of Vesuvius. The latter is seen in process of construction just as striæ, moraines, etc., are seen in the process of formation. As well might geologists speak of the oceanic theory with reference to rock strata as longer to speak of the glacial theory with reference to glacial deposits.

EDITORIAL COMMENT.

The West Coast of Greenland.

In a recent article by David White and Charles Schuchert, of the U. S. National Museum, published by the Geological Society of America, the authors come to the following conclusions. The observations were made in the summer of 1897 in connection with the expedition of Lieut. Peary of that year:

(1) The Cretaceous and Tertiary rocks in the region described lie everywhere unconformably upon a hilly basement of old crystallines, chiefly gneiss and diorite (Kaersut, Pagtorfik, Ekorfat), or upon early Cretaceous or pre-Cretaceous (?) basalts (Niakornat, Alinaitsunguak, Atanikerdluk). The greatest altitude of the sedimentary terranes is at Atanikerdluk, 3,040 feet above sealevel. The old basalts are highly altered and usually occur as breccias (Niakornat, Alinaitsunguak).

(2) The prevailing easterly dips of the Lower Cretaceous along the north side of Nugsuak peninsula, in which the strata should dip westerly, since it is in that direction that the nigher and younger beds appear, may be in part explained by fault compensation, as illustrated at Ujarartorsuak. A certain degree of irregularity of dip, the variable and often strong coastward dips, as well as the low altitude of the Tertiary at its eastern border on the south side of the peninsula (Atanikerdluk), are probably due to inequality in the post-Tertiary epeirogenic movements.

(3) The sediments appear to have been derived from the east, since the light-colored sandstones and conglomerates are

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most abundant on that side of the sedimentary belt (Kook, Kaersut), where marine fossils appear to be wanting. At one of the eastern localities (Ujarartorsuak) fresh-water shells occur with plants. To the west, dark homogeneous shales with abundant remains of marine animals predominate.

(4) Sedimentation appears to have been continuous in some portion of this region throughout Cretaceous and early Tertiary times, since no marked unconformities or unmistakable evidence of interruption of deposition have been seen. In certain sections, however, there appears to be, either in a variable thickness of the series or a slight difference of attitude, evidence of movements or erosion prior to the imposition of the Tertiary basalt cap, though these may be only local or of minor extent. But in many well exposed sections there is no local trace of sedimentary discontinuity between the Mesozoic and Tertiary.

(5) The entire thickness of the clastic deposits is probably over 3,500 feet. They are divided by Heer into four series, on the basis of their vegetable contents. Of the lowest of these, the Kome series, developed on the north coast of the peninsula, a thickness of probably not over 700 feet is exposed above tide. The discovery of additional dicotyledons in the Kome series, from which hitherto only Populus primæva was known, and which was regarded as Urgonian in age by Heer, casts serious doubt on the reference of those beds to so low a stage in the Lower Cretaceous. The flora as a whole is, however, to be compared with that of the Virginian Potomac formation, with some, perhaps the upper, portion of which the Kome series is probably synchronous.

The Atane series, hitherto not positively known on the north shore of Nugsuak peninsula, is clearly present at Ujarartorsuak with characteristic Atane plants. Farther west, at Kook Angnertunek and Niakornat, the dark homogeneous shale series probably represents both the Atane and Patoot members of the Upper Cretaceous, since of the marine organisms found here some are identical with those occurring at Ata and Patoot, the typical localities for the two divisions of the Upper Cretaceous. The marine invertebrates from the Atane series, which Heer correlated by means of fossil plants with the Cenomanian of Europe, strongly indicate that the

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series is to be correlated with the Fort Pierre and Fox Hills or Montana formation of the western United States. Paleobotanically the Atane series is so closely related to the Vineyard series of Marthas Vineyard, the Amboy clays of the Raritan region of New Jersey, or the uppermost Potomac of Alabama as to furnish strong reason for the belief that the middle of Heer's groups is the Greenland contemporary of the Amboy clays. The Patoot series, which appears lithologically and stratigraphically to be inseparable from the Atane series, contains at the same time many plants common in the upper part of the Amboy clays, with others allied more closely to the higher Cretaceous floras, such as that of the Laramie. The Patoot series may perhaps be safely interpreted as constituting a paleontological as well as sedimentary transition from the Atane series to the Tertiary. The thickness of the Atane and Patoot series (Senonian) is not less than 1,300 feet and may considerably exceed this.

The Tertiary clastics at Atanikerdluk attain a thickness of not less than 1,500 feet, not including the intruded basalts at least 200 feet thick. The horizon of most of the plants described by Heer as Miocene is assumed to be near the base of that series, the demarkation of which appears to be purely arbitrary.* It is more probable that the age of the plants now generally conceded by paleobotanists to be Oligocene may even be Eocene instead of Miocene. No remains of marine animals have as yet been discovered with these plants.

The Tertiary clastic zone appears to be thinner west of Atanikerdluk, and at Patoot and Atane it is presumably represented by the upper sandstone horizon 200 to 300 feet in thickness. At the western end of the peninsula its presence is established in the occurrence of "Atanikerdluk" plants. On the north coast east of Niakornat there may be a slight development of this zone, and it evidently is represented in the interior east of Kook.

The systematic differentiation of the described plant material from the Greenland Cretaceous, by means of which so important a distinction between the floras of the three series,

*The conglomeratic sandstone at 1,000 feet above tide at Atanikerdluk, assumed by the writers to be the base of the Tertiary at that point, is the only hypothetical lithological bench mark observed in any section.

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as well as such voluminous local floras, was attained, appears to have necessitated a refinement in species separation that seems in many cases to be impracticable if not impossible of satisfactory recognition.

(6) An apparent angle between the horizontally bedded Tertiary basalt and the supposed Upper Cretaceous sediments west of Niakornat may warrant the hypothesis of Tertiary erosion in that vicinity. On the south coast, at Atane and Patoot, the Tertiary sediments are thought to be thinner than at Atanikerdluk, which lends further support to this supposition.

(7) The entire region of the west coast of Greenland in which Mesozoic or Tertiary sediments are now found is capped by a great number of superimposed, approximately horizontal, non-columnar basalt beds of varying thickness and of great extent. Frequently 3,000 feet of this basalt cap remains, while at Kilertinguak (6,250 feet above tide) over 4,000 feet is preserved.

In certain regions numerous dikes intersect at varying angles the Cretaceous, Tertiary, and even the lower portion of the basalt cap, and are frequently found both forking and intersecting. Intruded basalts are not rare, especially in the Tertiary. The peridotite intrusive beds, about 350 feet thick, back of Kaersut are probably of Tertiary age, as are also the other high intercalated basalts.

At the time of the great elevation of the region, probably in the late Tertiary, the basalt cap, which, judged by the development on Unbekanntes island, may have exceeded 7,000 feet in thickness, most probably extended in an unbroken sheet from the south of Disko island north to beyond the Svartenhuk peninsula, a distance of 250 miles.

(8) The dissection of this great basalt sheet, the development of the Vaigat, the Umanak fiordal system, the isolation of Disko—in fact, approximately the present land topography of this coast—were accomplished at a much greater elevation during Pleistocene time.

(9) Evidence of post-Pleistocene subsidence, with Arctic climatic conditions, is found in the presence of recent Arctic marine shells occurring in terraces at an elevation of from 100 to 150 feet above tide. In the old crystalline region much

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farther south the terracing is said to extend to 300 feet above tide.

(10) The extent of the more recent uplift is not known, since the retreat of glaciers, the inundation of ancient dwelling sites, and the records of tide gauges point to present downward movement observable within historical time.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Geological Survey of Georgia. Preliminary report on a part of the Phosphates and Marls of Georgia. S. W. McCallie. (Bulletin No. 5-A. of the Georgia survey publications).

The author prefaces his report by a brief review of the phosphate deposits of other countries, viz. those of England, Wales, Belgium, France, Spain, Russia, Germany, Norway, Tunis, Algiers and Canada. He also sketches the phosphates of South Carolina, Florida and Tennessee. He also notes at some length the different theories that have been proposed for the origin of important deposits of phosphate of lime.

These deposits in Georgia are in the southern part of the state, and are probably an extension of those recently exploited in Florida. They are described in Decatur, Thomas, Brooks, Lowndes, Echols, Camden, Glynn and McIntosh counties. These counties contain more or less of low grade phosphate, but according to Prof. McCallie, probably not enough of sufficient purity to encourage an expectation of profitable mining, but quite sufficient to be of great value to the agricultural interests of the region, and especially in the regeneration of exhausted lands.

N. H. W.

On the Interglacial Submergence of Great Britain. By Henr. Munthe. Bulletin of the Geological Institution of the University of Upsala, Vol. III, for 1896-97, pp. 369-411, with map and sections; Upsala, 1898.

During a visit of a few weeks to England and Scotland in the summer of 1897, the author there continued his examination of the glacial drift and associated marine deposits, on which he had previously published important papers from his studies in Sweden and around the Baltic sea. The interglacial beds specially described in this paper are in Scotland, comprising (1) sections in the ravines of three streams near the middle of the west side of the peninsula of Kintyre (Cantire), and (2) the section at Clava in the Nairn valley, six miles east of Inverness. These are the most interesting fossiliferous interglacial beds known in the British Isles; and probably the most significant investigation of any of their sections has been made by Dr. Munthe, as here noted, at Cleongart, the most northern of the Kintyre

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localities. His collections of the fossils from successive levels of the Cleongart section demonstrate its marine deposition through the evidence of changes of the fauna due to changes in the temperature and depth of the sea. It is now made impossible to suppose (as might before have seemed a tenable hypothesis) that the materials of this deposit, together with its organic contents, were washed by drainage from superglacial or subglacial drift, after having been glacially transported from the old sea bed east of Kintyre over which this part of the ice-sheet had advanced.

At Cleongart the shell-bearing deposit is stratified clay, 27 feet thick, of dark bluish gray color (excepting its upper four feet, which, nearly like the overlying till, is weathered to a brown or chocolate color), comparatively free from stones in its upper part, but containing, throughout its whole thickness, scattered small rounded and angular stones, including rarely one that is glacially striated. Near the middle is a layer of about six inches of "a veritable boulder-clay," in which no organic remains occur.

Above the shell-bearing clay, a grassy slope of boulder-clay (till), which is destitute of fossils, rises 74 feet in a distance of about 150 feet, to an arable field at the top of the ravine. From that point a boring (made by a committee of the British Association, whose report is published in the Proceedings of the Liverpool Meeting, 1896) went down 76 feet through the till, and was continued in the shelly clay 21 feet farther, thus proving a considerable southward extension of the stratified clay. Beneath, in the exposed section and the adjacent stream course, is a bed of sand and gravel, which appears to be of glacial origin, 11 feet thick, to underlying mica schist.

The top of the Cleongart fossiliferous bed is 178 feet above the sea. (These figures, and most of the definite measurements preceding and following, are from the report of the Association committee; while the descriptions of the section are partly from this report, being supplemented by Dr. Munthe's observations.) About a mile distant to the south, in the Drumore glen, the top of a similar shelly clay, also there overlain by till, is 199 feet above the sea; and in the Tangy glen, about three miles farther south, where the Kintyre interglacial marine fossils were first detected in 1873, the top of the shelly clay, 13 feet or more in thickness, is at the altitude of 135 feet, and is overlain by about 30 feet of till.

Forty-five species of mollusca, all of which still live in European seas, are identified from the Cleongart section, as shown by combining the lists of Dr. David Robertson, in the Association report, and those of Dr. Munthe; but the most instructive collections were made by the latter in carefully washing samples of the clay taken from twelve different levels. The fossils from the lowest accessible part of the bed, including Cardium grönlandicum, Leda pernula, and Yoldia lenticula, indicate arctic conditions, nearness of the ice-sheet, and a depth of at least about 40 meters (130 feet), the depression of the land being therefore about 300 feet, or more, below its present level. Nearly the same severe temperature and considerable depth of sea are indicated

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upward for the next six or seven feet, to a hight of about twelve feet above the base of the stratified clay, including, at the top of this portion, the layer of till before mentioned, half a foot thick, in which fossils are wanting. Thence upward, the first fossils noted are arctic and boreal; but at three feet above the thin till deposit the frequent occurrence of Turritella terebra implies a more temperate sea, and this species, with others of Astarte and Cardium, denote a depth between 20 and 75 feet. Similar mild temperature and moderate depth are shown for the next six feet vertically. Lastly the temperature of the sea became again arctic, and its depth appears to have increased again to at least about 130 feet, denoting a vertical submergence of fully 300 feet.

Throughout this deposit of stratified clay (excepting its inclosed thin layer of till) foraminifera occur plentifully, but with important variations in the vertical range of species. Their number in Robertson's list is 83, and in Munthe's list 112, the number common to both lists being 59. These, and the ostracoda likewise, afford less information than the mollusca concerning the physical conditions of the sea in which the deposition took place; but they seem to present no evidence of a contradictory character, such as might bring any doubt against the conclusions before stated.

An earlier report by the same committee of the British Association, published in 1893, giving details of their examination of the Clava section, is discussed by Dr. Munthe in the last nine pages of his paper. This report, and later articles on the same subject by Mr. Dugald Bell, a member of the committee, were noticed, with full notes of the section, by the present reviewer in the American Geologist for January, 1896 (vol. xvii, pp. 45-47), with approval of the minority report of that committee (by Dugald Bell and Prof. Percy F. Kendall), in which the Clava clay and its shells, occurring at the altitude of 487 to 503 feet above the sea, are supposed to have been supplied from an ice-sheet that had eroded preglacial marine beds from the basin of Loch Ness (now about 50 feet above the sea and 774 feet deep), depositing the Clava strata in a glacial lakelet held temporarily in a nook of the Nairn valley by a barrier of ice which later advanced again, forming the overlying till. From this opinion I yet see no sufficient reason to recede, although Prof. James Geikie, in "The Great Ice Age" (third ed., 1894, pp. 139-143, 155), and Dr. Munthe, in this paper, strenuously argue for the marine deposition of the fossiliferous Clava bed. Perhaps the most noteworthy objection to their view which can be drawn from the Clava fossils is the occurrence together there, in considerable numbers, of Litorina litorea, a species whose habitat is limited to shores and very shallow water, and other species, as Leda pernula and Natica grönlandica, which are unknown as shore species but live in depths of 20 to 50 fathoms or more. The assemblage of fossils at Clava, including 23 species of mollusca, seems to me most accordant with their reference to glacial transportation, while the absence of marine beds at similar altitudes elsewhere throughout the British Isles further enforces the same explanation.

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Dr. Munthe errs in his supposition (following the majority report of the committee) that the transportation of the Clava strata must be thought to have been en masse, as a part of the old sea bed on the site of Loch Ness removed bodily by the ice sheet, carried probably ten or fifteen miles or more, and laid down bodily in a horizontal position under the 43 feet of till, which there forms the surface. Instead, the materials of the Clava beds and their included fossils are probably modified drift washed by drainage from the englacial and finally superglacial drift of this part of the waning Scottish ice-sheet. In his final paragraph, Dr. Munthe takes occasion to disclaim any intention of attributing the glacially transported shelly beds of Moel Tryfan and other high level localities in northern Wales, northwestern England, eastern Ireland, and southwestern Scotland, to a marine origin. These beds of shell-bearing modified drift, sometimes of great extent and thickness, and frequently overlain by till, occurring up to the altitude of 1,300 feet above the sea, appear to me referable to nearly the same processes as the stratified beds of clay, sand, and gravel, under the Clava till.

From the moderate temperature of the sea at Cleongart during a part of the time of formation of its stratified clay, Dr. Munthe infers that Britain had then a long interglacial epoch, with a climate nearly the same as to-day. On the other hand, from a consideration of the conditions of climate, fauna, and flora, adjoining and upon the Malaspina ice-sheet in Alaska, it may, as I believe, be more probably supposed that only a short retreat and perhaps only a short re-advance of the ice-sheet, not long separated in time, were sufficient to permit the marine beds of Kintyre to be formed and to become enveloped by their covering of till. W. U.

Geological Survey of Georgia. Preliminary report on a part of the water-powers of Georgia. Compiled from notes of C. C. ANDERSON and other sources by B. M. HALL. (Bulletin 3–A. of the publications of the Geological Survey of Georgia).

Mr. Anderson did this work under appointment while Dr. J. W. Spencer was state geologist, and more recently it has been extended by Mr. Hall, under the direction of state geologist Yeates, in connection with the hydrographical work of the United States Geological Survey. The report comprises a great amount of accurate details respecting the surface drainage of the state, each of the principal rivers having been examined at the location of the chief water-powers. The tables give the cubic feet of flowage per second, the fall in feet, the length of the shoal, the horse power and other general information. Other tables specify the amount and kind of improvement, number of mills, horse power used, elevations above the sea at railroad stations and the results of daily gauging of several streams during two or three years. As an economical report it is very valuable, for water power is increasing in value, because of its easy transmission as electricity. We wish to commend especially the excellent index, for no such report should be issued without an index, but we cannot approve the peculiar and copious use of commas which punctuate the text. N. H. W.

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MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Adams, G. I.

A geological reconnoisance in Grant, Garfield and Woods counties, Oklahoma. (Kansas Univ. Quarterly, vol. 7, s er. A, pp. 121-124, pls. 11-12, July 1898.)

Agassiz, Alexander.

The Tertiary elevated limestone reefs of Fiji. (Am. Jour. Sci., ser. 4, vol. 6, pp. 165-167, Aug. 1898.)

Aguilar, Rafael.

Bibliograféa geológica y minera de la republica Mexicana. (Instituto Geologico de Mexico, pp. x and 159, Mexico, 1898.)

Baur, George.

[Sketch of, by O. P. Hay.] (Science, new ser., vol. 8, pp. 68-71, July 15, 1898.)

Blake, W. P.

Remains of a species of Bos in the Quaternary of Arizona. (Am. Geol., vol. 22, pp. 65-72, Aug. 1898.)

Bolton, Herbert.

The Lancashire coal field. (Trans. N. Y. Acad. Sci., vol. 16, pp. 224-251, 1898.)

Branner, J. C.

On the origin of novaculites and related rocks. (Jour. Geol., vol. 6, pp. 368-371, May-June 1898.)

Calvin, Samuel.

Contribution to "A symposium on the classification and nomenclature of geologic time-divisions." (Jour. Geol., vol. 6, pp. 352-355, May-June 1898.)

Case, E. C.

The development and geological relations of the vertebrates. Pt. I. The fishes. (Jour. Geol., vol. 6, pp. 393-416, May-June 1898.)

Chamberlin, T. C.

A supplementary hypothesis respecting the origin of the loess of the Mississippi valley. [Abstract.] (Proc. A. A. A. S., vol. 46, pp. 204-205, June 1898.)

Clark, W. B.

Contribution to "A symposium on the classification and nomenclature of geologic time-divisions." (Jour. Geol., vol. 6, pp. 340-342, May-June 1898.)

*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

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A study of some examples of rock variation. (Jour. Geol., vol. 6, pp. 372-392, May-June 1898.)

[Cope, E. D.]

Edward Drinker Cope, naturalist—A chapter in the history of science. By Theodore Gill. (Proc. A. A. A. S., vol. 46, pp. 1-30, June 1898.)

Dean, Bashford.

Note on the ventral armoring of Dinichthys. (Trans. N. Y. Acad. Sci., vol. 16, pp. 57-61, 1898.)

Dean, Bashford.

On a new species of Edestus, E. lecontei, from Nevada. (Trans. N. Y. Acad. Sci., vol. 16, pp. 61-69, 1898.)

Derby, O. A.

Notes on Arkansas novaculite. (Jour. Geol., vol. 6, pp. 366-368, May-June 1898.)

Eastman, C. R.

Dentition of Devonian Ptyctodontidæ. (Am. Nat., vol. 32, pp. 473-488, July 1898.)

Eastman, C. R.

On remains of Struthiolithus chersonensis from northern China, with remarks on the distribution of struthious birds. (Bull. Mus. Comp. Zool., vol. 32, no. 7, pp. 127-144, 1 pl., Aug. 1898.)

Eaton, G. F.

The prehistoric fauna of Block island, as indicated by its ancient shell-heaps. (Am. Jour. Sci., ser. 4, vol. 6, pp. 137-159, pls. 2-3, Aug. 1898.)

Foote, W. M.

Note on the occurrence of native lead with roeblingite, native copper, and other minerals at Franklin Furnace, N. J. (Am. Jour. Sci., ser. 4, vol. 6, pp. 187-188, Aug. 1898.)

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Gilbert, G. K.

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Gilbert, G. K.

Origin of the physical features of the United States. (Nat. Geog. Mag., vol. 9, pp. 308-317, pls. 8-9, July 1898.)

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On the skull of Xerobates (?) undata Cope. (Kansas Univ. Quarterly, vol. 7, ser. A, pp. 143-148, July 1898.)

Gill, Theodore.

Edward Drinker Cope, naturalist—A chapter in the history of science. (Proc. A. A. A. S., vol. 46, pp. 1-30, June 1898.)

Hay, O. P.

George Baur. (Science, new ser., vol. 8, pp. 68-71, July 15, 1898.)

Hershey, O. H.

Notes on the geology of Jamaica. (Science, new ser., vol. 8, pp. 154-155, Aug. 5, 1898.)

Hershey, O. H.

Raised shoe-lines on cape Maysi, Cuba. (Science, new ser., vol. 8, pp. 179-180, Aug. 12, 1898.)

Hollick, Arthur.

Geological notes. Long island and Block island. (Trans. N. Y. Acad. Sci., vol. 16, pp. 9-18, 1898.)

Hollick, Arthur.

The Cretaceous clay marl exposure at Cliffwood, N. J. (Trans. N. Y. Acad. Sci., vol. 16, pp. 124-136, pls. 11-14, 1898.)

Hollick, Arthur.

Appendix [to "A new investigation of man's antiquity at Trenton" by H. C. Mercer]. [Abstract.] (Proc. A. A. A. S., vol. 46, pp. 378-380, June 1898.)

Holmes, W. H.

Primitive man in the Delaware valley. [Abstract.] (Proc. A. A. A. S., vol. 46, pp. 364-370, June 1898.)

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The glacial or post-glacial diversion of the Bronx river from its old channel. (Trans. N. Y. Acad. Sci., vol. 16, pp. 18-24, 1898.)

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Probable stratigraphical equivalents of the Coal Measures of Arkansas. (Jour. Geol., vol. 6, pp. 356-365, May-June 1898.)

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Remarks on the classification of the Mississippian series. (Am. Geol., vol. 22, pp. 108-113, Aug. 1898.)

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On the implement-bearing sand deposits at Trenton, N. J. [Abstract.] (Proc. A. A. A. S., vol. 46, p. 350, June 1898.)

Kummel, H. B.

The age of the artifact-bearing sand at Trenton. [Abstract.] (Proc. A. A. A. S., vol. 46, pp. 348-350, June 1898.)

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The Jurassic formation on the Atlantic coast.—Supplement. (Am. Jour. Sci., ser. 4, vol. 6, pp. 105-115, Aug. 1898.)

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Merrill, F. J. H.

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Merrill, F. J. H.

The origin of the serpentines in the vicinity of New York. (50th Ann. Rept. N. Y. State Museum, vol. 1, pp. 32-44, pls. 6-8, 1898.)

Merrill, F. J. H.

Preliminary list of public geological and mineralogical collections in the United States and Canada. (50th Ann. Rept. N. Y. State Museum, vol. 1, pp. 45-74, 1898.)

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The hypothesis of a Cincinnati Silurian island. (Am. Geol., vol. 22, pp. 78-85, Aug. 1898.)

Moses, A. J.

Some new appliances and methods for the study of crystals. (Trans. N. Y. Acad. Sci., vol. 16, pp. 45-57, 1898.)

Newland, D. H.

Notes on the eclogite of the Bavarian Fichtelgebirge. (Trans. N. Y. Acad. Sci., vol 16. pp. 24-29, 1898.)

Nicholas, F. C.

The mountains and Tertiary valleys of eastern Colombia. (Trans. N. Y. Acad. Sci., vol. 16, pp. 166-181, pl. 15, 1898.)

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Wasatch and Bridger beds in the Huerfano lake basin. [Abstract.] (Proc. A. A. A. S., vol. 46, pp. 205-206, June 1898.)

Penck, Albrecht.

Changes of level in the glacial formations of the Alps. [Abstract.] (Proc. A. A. A. S., vol. 46, pp. 203-204, June 1898.)

Putnam, F. W.

Early man of the Delaware valley. [Abstract.] (Proc. A. A. A. S., vol. 46, pp. 344-348, June 1898.)

Rice, W. N.

A suggestion in regard to the theory of volcanoes. [Abstract.] (Proc. A. A. A. S., vol. 46, pp. 199-200, June 1898.)

Ries, Heinrich.

Note on a beryl crystal from New York city. (Trans. N. Y. Acad. Sci., vol. 16, pp. 329-330, 1898.)

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On the origin and age of the relic-bearing sand at Trenton, N. J. [Abstract.] (Proc. A. A. A. S., vol. 46, pp. 350-355, June 1898.)

Stevenson, J. J.

Notes on the geology of the Bermudas. (Trans. N. Y. Acad. Sci., vol. 16, pp. 96-124, pls. 8-10, 1898.)

Taylor, F. B.

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GLACIAL PHENOMENA IN OKANOGAN COUNTY, WASHINGTON.

By WILLIAM L. DAWSON.

In taking up the study of this great mountain county, it seems necessary to state that no systematic work, apart from that incident to mining operations, has ever been carried on here except that done last year, the results of which are not published yet. Hence this paper can only record scattering observations and a few inferences drawn from them in this large and little explored field. Mr. Bailey Willis in 1887 took a hasty survey of the facts in the northern part of the county and along the Columbia river, publishing them briefly in his "Changes in River Courses in Washington Territory Due to Glaciation." (Bull. No. 40, U. S. Geol. Surv.) Israel Cook Russell, in the employ of the United States geological survey, visited the region about Chelan during the summer of '92, and makes some notes in Bulletin No. 108 (U. S. Geol. Surv.), entitled "A Geological Reconnoisance in Central Washington." It is to him that I am indebted for many of the facts in northern Douglas county, which need to be referred to in order to make our present subject intelligible. It was the writer's privilege to spend some fourteen months in Okanogan county, from June, 1895, to August, 1896. With headquarters at Chelan, tours were made through all the principal valleys, and three or four expeditions were made in addition to the high mountains about the head of lake Chelan. The Indian reservation, embracing all the land east of the Okanogan river, was not visited.

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With an area nearly equal to that of New Jersey, Okanogan county may be characterized as a very mountainous region. Proceeding from the Cascade spurs and foothills, whose bases the Columbia river washes, throughout the course of its "big bend" at an altitude of only 600 or 700 feet, the county rises rapidly to the west and north, culminating in an alpine region on the west and north-west, which abounds in glacier-scored peaks and bleak aiguilles ranging in hight to 10,000 feet. The mountains being composed almost exclusively of crystalline rocks, the scenery is bold and rugged in the extreme.

The drainage is effected by five principal streams which flow south-east or south to join the Columbia river. Of these perhaps the oldest in point of origin, but certainly the newest in its immediate surroundings is the Chelan river, which drains the lake of the same name. In width a river, but in depth exceeding any of its kind yet measured in North America, lake Chelan winds for 60 miles between precipitous mountains, whose bases meet at least 1500 feet below. Starting from the head of the lake at an altitude of 970 feet, the valley is continued for 30 miles into the heart of the highest Alps and drained into the lake by the Stehekin river. Rising in a chain of lakes in British Columbia, the Okanogan river passes through the county with a broad valley, in a course almost due south. With reference to its present conditions, it is to be reckoned one of the oldest streams in eastern Washington, since with the help of a little "lining up," it can be navigated to its head in Okanogan lake. It meanders along a valley floor which is often a mile in width, and this is greatly augmented in places by the flat-topped terraces, of which I shall speak later. Midway between these two streams lies the Methow river, a rapid, treacherous stream which runs for a hundred miles or so wholly within the limits of the county. A smaller stream, the Entiat, parallels lake Chelan, which lies to the eastward, in a narrow valley; while the Wenatchee river bounds the county on the south-west.

Of these rivers nothing more need be said until we come to the consideration of glacial phenomena. But the preglacial course of the Columbia river, which is also the present course, needs to be accounted for. It can be done by refer-

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ence to the country rocks. The rocks of the great Cascade upheaval, so far as now observable in Okanogan county, west of the Okanogan river, are almost entirely crystalline. These rocks compose the west bank of the Columbia river from Wenatchee to the mouth of the Okanogan. The east bank, on the contrary, throughout this course, presents an unbroken escarpment of basalt rising 2000 feet high, which terminates the big bend plateau on the west. This is the edge of the lava sheet; and although the crystalline rocks do at places crop out from beneath on the east bank, they are always covered thickly with the basalt capping. The river, whose former, more direct course lay far to the eastward, was pushed over against the granite by the advancing lava flood, and its future course was prescribed by the western limits of the lava; and, as Bailey Willis has well pointed out, the course from old Ft. Spokane to the mouth of the Okanogan was determined by the resultant line of depression between the north-bound flow of the Big Bend region, and the south-bound flow, which covers the present Colville Indian reservation.

Then as to its minor topographical features: we find in this county, and especially in the lower mountain ranges, a number of peculiar valleys, deep and narrow, called coulées commonly pronounced "cool'ies." This name is applied to such valleys, whether short or extensive, as are unoccupied, or at least not adequately occupied by running water, and have comparatively level floors. Toat's coulée, with its dependencies in the northern part of the county; Antoine coulée, from the Methow to the Columbia; Knapp's and Navarre's coulées, which cut through the range between lake Chelan and the Columbia, may be cited as examples. The problem of coulée formation offers one of the most inviting subjects which we shall attempt to discuss in this paper.

Scarcely less noteworthy features of this region are the terraces which line the principal streams. Those along the Columbia river are about 300 feet above the stream, and at favorable points along the river present a surface of several square miles. The Okanogan river, likewise, is terraced throughout its length. The terraces of the more rapid streams, owing to the varied character of their gorges, are more irregular and infrequent.

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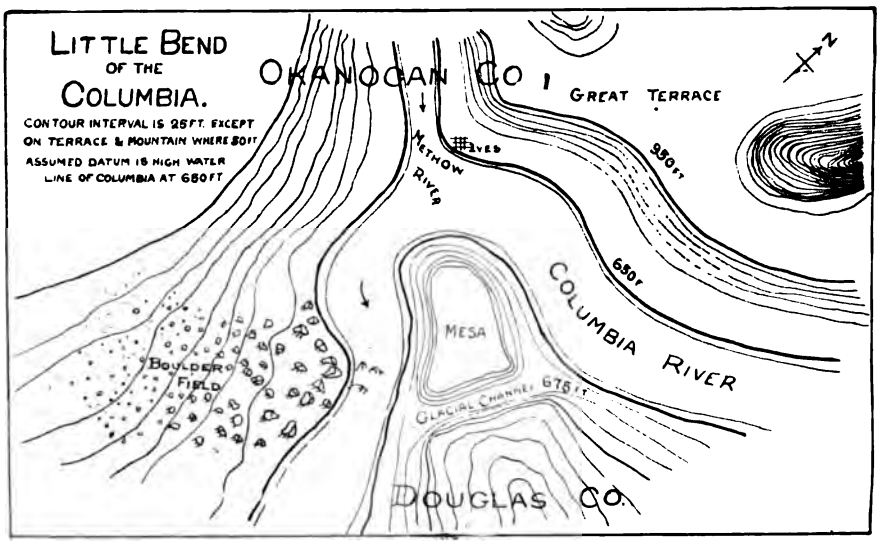


Diagram No. 1.

Any more detailed description of the topographic features would anticipate points that I shall hope to bring out in considering the phenomena in connection with the glacial period. The evidence of ice action in Okanogan county is most pronounced. Indeed, one has only to note the fresh appearance of terminal moraines, kettle-holes and terraces, together with the occurrence of glaciers by the score on the western ranges, to be convinced that the ice age has retreated none too soon. Although the glaciation of this region was not effected by a general ice-sheet, it is because the work was accomplished by a local and somewhat restricted action, that the results present certain unique features. We should expect that in the several phases of advance and retreat the glaciers would be largely obedient to the conditions imposed by the previous valleys of erosion. And furthermore, although we should concede a general condition of moisture and precipitation throughout the region, the varying hights of the mountains and the differing widths of the valleys would principally determine the lower limits of the advancing glaciers. Hence we are to look for no regular ice-sheet margin, but to remember that each individual glacier will halt or deploy upon the plain in a manner depending on the size of its area of accumulation, its distance, and gradient from the divide.

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Three such glaciers swept down the Chelan, Methow, and Okanogan valleys, respectively. Of these we may well believe that the Chelan glacier, both on account of the narrowness of its valley and the hight of its mountains, was the first to reach the Columbia river. In doing so, it forced out the waters of the pre-glacial lake Chelan, which must have existed at a level some 400 feet below the present one, as a lateral reservoir of the Columbia river. Upon reaching the Columbia, instead of at once and effectually damming up the stream, in the struggle which ensued the glacier was held in check and its foot dissolved by the impetuous river. Besides this it had lateral means of discharge through Knapp's and Navarre's coulées;—hereafter to be more particularly described. These lateral ice-streams also emerged upon the Columbia river, but at a lower point, where the valley is wider; and today great benches and banks of morainic and half-sorted material may be found distributed for several miles on the Douglas county side of the river.

The Methow glacier reached the Columbia some time later, encountering it at a point which may be called the little bend. For here the river, after pursuing a general westerly course for upwards of 80 miles, turns sharply within the space of half a mile to begin its southern course. At this exact point the Methow valley opens to the west. And here is preserved a most interesting record of the time when the ice from the west began to encroach upon the river channel. Upon becoming dammed the river rose to a hight sufficient to enable it to cut across the corner, where it excavated a deep transverse channel some 150 feet down into the granite,—as shown by accompanying diagram (No. 1). The glacier, being relieved laterally, left the river in undisturbed possession until the final damming of its waters by the Okanogan glacier.

It is by this latter glacier that the hardest work was done. Being produced by a drainage area 200 miles long and 6000 miles in extent, it was slow in coming, but when it did arrive it was not to be stopped by the Columbia gorge. It occupied this latter completely, dividing right and left, but even so it could not find relief for its great bulk and enormous pressure. According to Russell it rose and overtopped the plateau op-

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posite, although it is especially guarded at that point by a mountain rampart 2500 feet above the river. Arrived upon this great upland plain, the glacier deployed to the south and east, reaching as far as Coulée City in Douglas county. The evidence of this occupation is furnished by the bowlder-strewn prairies, miles in extent. Great masses of basalt were wrenched off from the edge of the plateau and deposited over the prairie in blocks up to 60 feet in diameter. The underlying granite as well is represented in the boulders.

The appearance of the Okanogan glacier was fraught with the gravest consequences to the Columbia river. Its waters were effectually dammed until they attained a hight sufficient to begin their glacial drainage southward through what is now called the Grand coulée. This valley, with a width of from one to four miles, bounded by perpendicular walls of basalt 400 feet high, though at present unoccupied except by stagnant lakes, was originally a fracture line in the lava, which subsequent preglacial streams drained to the north and south, from near Coulée City. The waters of the Columbia deepened this channel and planed down the divide. It had, however, to enter the southern portion by a waterfall approximately 400 feet high, in comparison with which Niagara is a mere bagatelle.

This brief account of the Grand coulée makes a fitting introduction to the subject of coulée formation. Recalling to mind our first definition of coulées as valleys which are unoccupied or at least not adequately occupied by running water, and which have comparatively level floors, we may need to add further that, in general, we shall expect to find these coulée floors with a low divide, sending the superficial drainage waters toward either end. This is done that we may exclude mere "draws" and dry creeks, and also valleys whose streams have been depleted by the capture of their headwaters. Thus limited, it will appear that the coulées of Okanogan and adjacent counties are ice formed,—either directly by ice action, or indirectly on account of the glacial occupation. With this in view, we may distinguish with reference to their origin three forms of coulées: 1. Valleys occupied temporarily by preglacial streams. 2. Preglacial valleys whose waters were permanently diverted by the ice. 3. Val-

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leys actually excavated by the ice. Other varieties are possible and innumerable modifications may be found, but from a somewhat careful study of the region I conclude these to be the leading types. Let us consider these three forms, with examples of each.

Of the first, Grand coulée must ever be the typical example. Enough perhaps has already been said to indicate its pertinent features. Moses' coulée to the westward may prove to be of this sort, but its phenomena have not been closely studied. Regarding it on the map, I have even hazarded the conjecture that it marks a stage of Columbia river drainage previous to the Grand coulée occupation, but this is, I confess, extremely improbable. The Little Bend coulée, already referred to, evidently belongs to this class. There was little opportunity for the formation of coulées of this class in Okanogan county proper because of the complete occupation of the ice.

Of the second class, the most prominent example is the one already figured by Bailey Willis, the old valley of the Similkameen river. This stream used to run south paralleling the Okanogan river for 30 or 40 miles, before joining it lower down. During the decadence of the glacial period the ice occupied this portion of its channel—being continually fed from the west—while the waters of the Similkameen, partially released, were accumulating on the north. Soon the water of the lake thus formed began to cut across a low divide to the east, and this action was continued until today the Similkameen deserts its old valley by a sudden sharp turn to the north-east, Miner's bend, and passes through a narrow, deep-cut canon to join the Okanogan at Oro. The glacier left abundant evidence of its presence in the old valley, for it heaped up morainic material in the central portions until a tributary stream, the Similihekin, upon entering the valley, turns and meanders slowly north over the drift, proceeding for 20 miles, or until it joins the Similkameen, in a direction contrary to the old stream;—certainly a remarkable instance of filial devotion in rivers. Of the southern extension of this coulée, Bailey Willis says: "From the Three Pools southward the drift surface is dotted with kettle holes. * * * The waters of Fish lake are held by a gravel dam, from beneath

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which a small stream escapes into the very narrow and crooked upper channel of the southern portion. The descent from Fish lake is very rapid, and is strewn with boulders of large size. After passing a very deep and narrow pool three-fourths of a mile long, into which the brook sinks, the valley opens out between limestone bluffs and drift terraces, and ends abruptly in a cul de sac at the head of Johnson creek, the further continuation, whether southward or south-eastward, being now completely filled." With regard to this alternative, I should unhesitatingly say that the preglacial drainage was through Johnson creek. Any one approaching the middle portion of the valley occupied by this little creek cannot but be impressed by its depth and width, as compared with the insignificant stream which drains it. It is, in fact, almost a coulée. In spite of nature's efforts to efface the record, this explanation is confirmed by a study of the derivation of the water which supplies Johnson's creek. The drainage of Fish lake is absorbed in the limestone belt, as indicated by the quotation from Bailey Willis; but a small stream called Scotch creek, which drains from the north-west, comes over the western terrace-wall of the Cul de sac through a slight notch, and is absorbed by the gravel before reaching the floor. This stream reappears a half mile or so east of the eastern rampart of the cul de sac, and is there called Johnson creek. The lower part of this Johnson creek coulée is choked effectually by the great terrace of the Okanogan, so that the mouth of the old valley cannot be determined. Upon the retreat of the glacier, the lower end of the old Similkameen valley terminating in the cul de sac, became filled with water. The lake thus formed was drained, not by the clearing away of the obstructing drift, but by a narrow defile cut in the solid granite, through which one may now pass horseback into Johnson creek. (See diagram No. 2.)

The drama thus enacted in the case of the Similkameen was reproduced on a smaller scale and in a simpler form a few miles south at Spring coulée. This name is applied to the lower end of the Salmon creek valley, below the point where the stream turns sharply to quit the valley by a narrow gorge running due east. So quickly and almost imperceptibly is this movement accomplished that in coming down the valley

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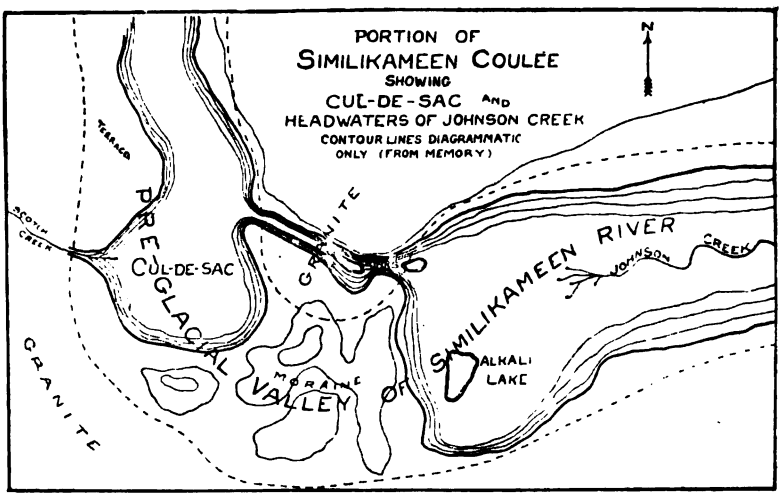


Diagram No. 2.

you are taken completely by surprise at finding yourself suddenly deserted by the stream. This is, of course, a simple recessional phase, the lower valley having been occupied for a long time by a persistent ice mass. (Diagram No. 3.)

Examples of the third class of coulées are the most numerous. The fact has already been referred to that the Chelan glacier found channels of discharge through a barrier range to the southward by means of Knapp's and Navarre's coulées. The latter of these is the larger and in some respects more remarkable, but the former has been more carefully studied and will be described briefly. An observer standing on the north side of lake Chelan across from the north end of Knapp's coulée sees a low divide cutting deeply through an east and west range of foothills, which rise from 1800 to 2500 feet above the level of the lake; cutting deeply, I say, yet not down to the lake level, for it ends, substantially, in a confusion of irregular terraces some 200 feet above the lake. Passing through the four or five miles' length of this coulée, we find that the central portion is level for quite a distance, and is bounded by abrupt mountain walls, while the slope in either direction toward the ends of the valley is only four or five per cent. It is an ice-hewn valley, a discharge pipe of the Chelan glacier. Originally consisting of two opposite valleys heading at near the same point on the divide, it was selected by the

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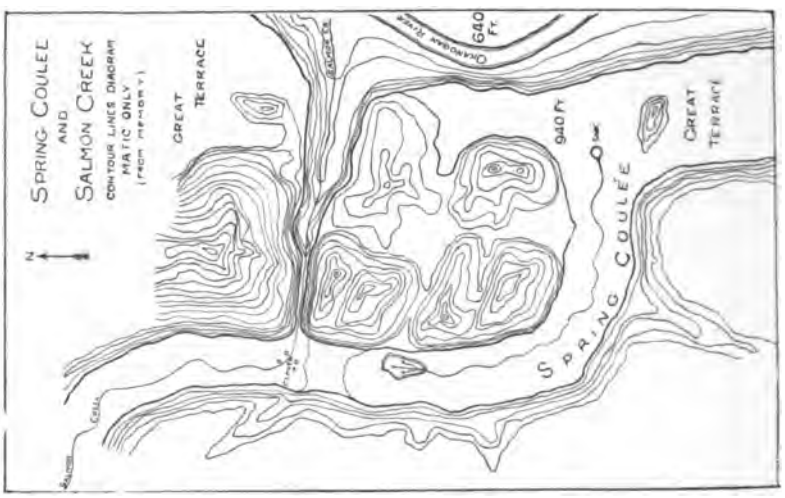


Diagram No. 3.

ice as presenting the easiest avenue of escape across the rampart; i. e., the lowest point, and was subsequently deeply excavated by the long continued and gradually concentrated ice-flow. Today its superficial features of kettle-holes and morainic banks have not been obliterated nor even noticeably modified by subsequent drainage.

(1). These recessional deposits are fairly characteristic of coulées of the third class, as also of the second. Antwine's coulée, which connects the Methow river at a point four miles above its mouth, with the Columbia river, over ten miles away, is so obstructed by local and foreign boulders that its passage is with difficulty effected on horse. Moreover, the lower or southern extension of this coulée is bounded by walls of terrace material, which were evidently accumulated at a time when the occupation of the Columbia gorge by the still moving Okanogan glacier prevented the free escape of drainage waters.

(2). Below the end of Antwine's coulée there exists another extending in substantially the same direction as the main Columbia valley. This latter is unique from the fact that its general outlines were probably determined by a split in the mountain, the portion toward the river falling away and revealing a fissure a thousand feet in depth, and scarcely wider

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at the top. The bottom of this rent, which is a mile in length, is occupied at present by glacial debris.

(3). To this third type also belong many small coulées which parallel for short distances the main valleys of the county. These are generally deep and narrow gorges which the ice has hollowed out between some sturdy outlying spur and its parent mountain. At least seven such well marked miniature coulées are to be found within a radius of four miles from Chelan.

Bearing no less emphatic testimony to the occupation by the ice, the terraces of Okanogan county deserve particular notice. I only regret that my observations with reference to these were not more accurate, and especially that a table of levels was not prepared. Mr. I. C. Russell has offered some comments upon the appearance of the terraces about Chelan, but I must confess that I cannot agree with some of his conclusions, and especially those relative to a lake Lewis. It might be that a careful re-examination of the facts would demonstrate the grounds for his supposition, but inasmuch as his pamphlet did not come into my hands until since my return, I must beg leave to explain the facts in another way, and to call attention in place to a few discrepancies in Mr. Russell's notes.

The subject may be divided into river terraces and lake terraces. To the former we have already alluded in the topographical sketch. In speaking of these features, Mr. Russell first describes a "great terrace" as noted in the Columbia valley a little below the mouth of the Chelan river, "the surface of which is 700 feet above the Columbia." Afterward he alludes to this "great terrace" repeatedly as appearing in his progress up the stream. Now this great terrace can be none other than the 300 foot terrace, which has notable expansions in the Howard or "poverty" flat, above the mouth of the Chelan river; in Paslay's bench above the mouth of the Methow; and in the Okanogan flats, with which also the great terrace of the Okanogan river is substantially continuous. Either Mr. Russell is mistaken in his estimate of the hight of the true, great terrace, or else at fault in trying to correlate his 700 foot terrace with the "great terrace." This point is important, for Mr. Russell on this mistaken supposition proceeds to correlate

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"a broad terrace 325 feet above the lake" in the Chelan valley with the "great terrace" of the Columbia valley, and for this purpose invokes the aid of a great post-glacial "lake Lewis," which should have formed the two terraces at the same time. The Chelan terrace, by the way, is more nearly 225 feet above the lake, and even so, some 250 feet above the top of the Columbia terrace.

We shall return in a moment to speak of the conditions at the foot of lake Chelan, but first a word further as to the Columbia terrace. That it is a river and not a lake formation would seem to be sufficiently evidenced by the fact that the terrace maintains its relative hight above the rivers—Columbia and Okanogan—throughout a distance of at least forty miles. Thus the absolute hight of the terrace increases as we ascend the streams. Furthermore, the material of the terraces shows nothing of the offshore gradation which we should expect in a still water deposit. This point cannot, of course, be urged if one insists with Russell that the whole channel was filled by lake-formed terrace deposits; but this is manifestly improbable.

The Chelan glacier, when it encountered the Columbia river, began to deposit a moraine across the mouth of its valley. This deposition was kept up at least until the Columbia valley was occupied by the southward flowing, west fork of the Okanogan glacier. As the ice began to retreat, it is possible to suppose that both the Chelan and Methow glaciers began to withdraw at first, while the Okanogan glacier still filled the Columbia gorge, and that the ice of the latter bulged into and followed the path of the retiring glaciers. This apparently out-of-the-way explanation is called for because of the remarkable presence of certain boulders in the Chelan and Methow valleys. Distributed all along the western bank of the Columbia river, and at certain points in the lower Methow and Chelan valleys, there occur large rounded masses of basalt, boulders, brought by the ice. I saw two on the Methow at least five miles from the mouth of the river. Another near lake Chelan weighing hundreds of tons lies half buried in the hillside about fifty feet above water on the north shore of the lake, and also five miles from the Columbia. The possible parent beds of these

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traveled blocks can be found only on the east bank of the Columbia or in the region east of the Okanogan river, that swept by the eastern flank of the Okanogan glacier. A notable aggregation of these boulders is to be seen in the Columbia valley a little below the entrance of the Methow. The appearance of the great boulder-field there found is difficult to account for. Starting on the bottom land only a little removed from the high water line of the Columbia river, large blocks of rock as big as houses are scattered over forty acres. As we ascend the gently sloping hillside going westward, we have to pick our way through promiscuously heaped boulders of gradually diminishing size. As we traverse the hill for a half a mile, we shall find a tolerably constant gradation of size until the upper limits of the field are obscured by terrace material. Now, throughout this rock scale the proportion of basalt to granitic boulders is about one in a hundred. They mark, perhaps, a recessional phase, at a time when the Okanogan glacier was held in check by the now released but swollen waters of the Methow, which forced the glacier to drop its load and was yet fierce enough to remove the finer material. Further than that, their present sorted appearance is hard to explain.

But to return to the subject of terraces: we notice that in the Chelan valley there must have been a time after the partial recession of the ice, while yet the ice occupied the Columbia gorge, when the pent-up waters filled the lower end of the valley. This feature is indicated at various levels, but especially at the 225 foot level, where the material of lateral moraines was worked over and spread out in benches, which are now capped by a fertile soil.

One of the late phases in the retreat of the lake waters is to be read in the Wapato district. This is a comparatively level section of land which occupies the angle of a bend in the lake, where it emerges from the north and south Narrows to open into the eastward-stretching terminal sheet. At the knee of this bend a valley opens westward. Down this valley a glacier flowed. Moreover, it did not tarry until its foot rested against the angle of the Wapato section, thus forcing the lake waters to cross between it and the highland opposite. The broad and shallow channel thus formed is now completely

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evacuated by the lake waters, and is occupied through its five or six miles extent only by occasional alkali sinks.

Lake Chelan is held in place by a dam of glacial debris. The terminal moraine of the Chelan glacier chokes up the lower valley and holds the lake back at a level 325 feet above that of the Columbia river, which sweeps its base. Instead of

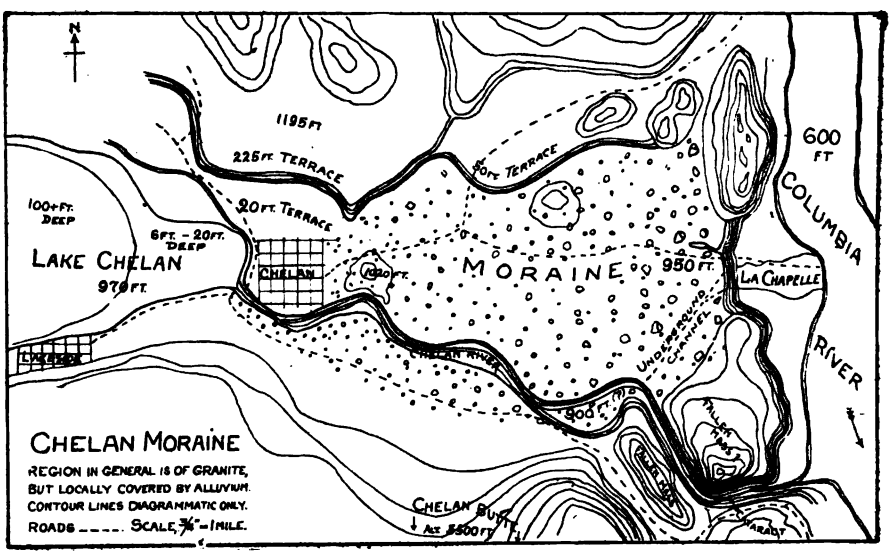


Diagram No. 4.

excavating a channel through the heaped-up materials of the moraine and so reducing the lake to its preglacial level, the outlet of lake Chelan has found another route,—a precipitous channel through the granite. This course is, perhaps, determined, as Mr. Russell suggests, by the fracture-line between two immense fallen rock masses, which were at some time split off from the north-east corner of Chelan butte. At the time of the Kokshut mountain disaster water coming from some point in the river burst forth from under the moraine, and has since persisted as a series of springs,—making a veritable garden spot at La Chapelle's landing, where was only barren sand before. If it be true that the Chelan river, instead of cutting through the granite, has merely followed a break in the rock, then no reliable estimate of its age can be formed on this basis. (See diagram No. 4.) Better results, however, may be ex-

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pected from work at the head of the lake, for the Stehekin river, which occupies the continuation of the valley to the west, has been filling in the head of the lake for a considerable time and has shortened its length by several miles.

No account of the ice work in Okanogan county would be complete without some reference to its present glaciers,—the residual members of the old ice system. Little has, however, been done to explore the ice fields which occupy the rugged region to the north and west of lake Chelan and the Methow river. Prospectors report them as being numerous throughout that country. From the summit of a high mountain west of Chelan, Wright's peak, itself bearing a small glacier, I have looked off upon a region where they might be counted by the score. Some of the central mountains seem to be completely covered with ice and snow, except for the aiguilles which pierce through. Although moist conditions still prevail, it is probable that we are witnessing a period of slow retreat.

MICROSCOPICAL LIGHT IN GEOLOGICAL DARKNESS.*

By E. W. Claypole, Akron, O.

Gems and other crystals had long been known, especially since the time of Brewster, to contain minute cavities partly or entirely filled with a liquid whose nature was unknown. But by the study of a few specimens Sorby succeeded in determining it in several cases. Among these was one which deserves to become classic on account of the peculiar advantage which it gave to our pioneer in the investigation. This was, indeed I hope I may say it is, though I do not know its present abode, a sapphire containing a cavity of a tubular form. It was so regular in its bore that it served the purpose of a natural thermometer, and by its use Mr. Sorby reached a conclusion at once surprising and important. I should mention that this little thermometer was one-fourth of an inch long by about one-eightieth of an inch in diameter, a truly microscopical instrument. On experimenting with

*Extract from the president's address before the American Microscopical Society, 1897.

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this little instrument Mr. Sorby found that the liquid, which, as shown, filled one-half of the cavity at ordinary temperatures such as 50° F., expanded so rapidly that its volume was doubled and the cavity was full at 89° F. This increase of bulk within so narrow limits of temperature at once excluded all ordinary liquids, and by further investigation and comparison Mr. Sorby was able to decide that the substance was nothing less than liquid carbonic acid, the only known liquid whose rate of expansion was equally great. Here was a solid fact contributed by the microscope toward the solution of some of the difficult and complicated problems presented by the physics of the earth's crust, and, again, we shall find from this study of a drop of liquid almost infinitely little, contained in an instrument equally minute, may flow results of great moment and far-reaching consequence. It is not the size but the solidity of the premises that authorizes the conclusions. Granting, as we must, that the little drop is carbon-dioxide in the liquid form, we can safely advance by reasoning on the known properties of this substance somewhat as follows:

The critical temperature of carbon-dioxide is about 88° F. (87.6°), that is to say, above this it exists only as a gas, and can by no pressure be liquified. Now it is in the highest degree improbable that at the time and in the conditions when the crystalline rocks were formed the surface of the earth was below this point. On the other hand, we may confidently rely on its having been far above this critical temperature. Obviously then the carbon-dioxide must have been sealed up in the crystals in a gaseous state—a bubble of carbonic anhydride. Here the problem becomes indeterminate. Both the original temperature and pressure are unknown. But arguing from what we know of the physics of this substance we may deduce the following conclusion: At present ordinary temperature, 50° F., the pressure in the microscopical registering thermometer of Mr. Sorby, must amount to about forty-eight atmospheres or 720 pounds on the square inch. This little instrument was exactly filled at 89° F., very near the critical temperature. At this point the minimum pressure which will enable the carbonic anhydride to retain the liquid state is seventy-three atmospheres or 1,100 pounds on the square inch. Consequently, if as inevitable, we assume a higher tempera-

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ture than 88° F. for the globe at the time of the crystallization of the minerals, we must also assume a higher pressure than seventy-three atmospheres as one of the conditions prevailing during crystallization.

This, however, is doubtless far too low for both. Instead of 88° Mr. Sorby and others consider the temperature of consolidation to have been nearer 700° F. Mr. J. C. Ward, a few years ago, following in the footprints of Mr. Sorby, carried his work a little farther. Assuming his datum of 680° F. as the temperature of crystallization of the minerals, he shows that the corresponding pressure was not less than twenty-six tons, or 3,500 atmospheres on the square inch, and that these microscopic flasks must have been charged with their effervescing contents under that enormous compression.

This is equal to the weight of a mass of overlying strata 52,000 feet thick. It is not right, however, to attribute the whole of this to the weight of overlying strata. There is no doubt that it is the resultant of this and the violent lateral compression to which the contortion and folding of the gneiss is due. The latter is probably the larger of the two components. Mr. Ward's conclusion is that the granite of Skiddaw, in England, was formed at least six miles below the surface, a depth at which the temperature is normally very near Mr. Sorby's datum of 680° F.

This is surely a vast deduction from data, microscopically minute, and seemingly insignificant. But insignificant as one of these "crystal flasks," as they have been aptly called, may be, we are not dealing with one alone but with vast numbers, for investigation has revealed them by myriads and by millions, and not in gems only, but in other crystalline minerals. In size they range between the one-thousandth and the fifty-thousandth of an inch, but they are so multitudinous as often to impart a white tint to the crystal, and many specimens of milky quartz owe their whiteness solely to the presence of these innumerable bubbles. In some of the Cornish granites the cavities make five per cent of the volume, and yield four pounds of the liquid to every ton of the rock.

Mr. Ward says: "Such is the minuteness of these cavities and their number in many cases, that more than a thousand millions might be contained easily within a cubic inch of

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quartz." We shall presently quote another writer giving the same testimony.

I must here digress for a short time from the main line to trace a tributary that meets it at this point and whose course it is necessary to have in mind in order to develop the argument. The geologist, regarding the past history of the globe with a critical eye, has long been amazed at the vast masses of mineral fuel—coal, petroleum and gas—which he finds accumulated in the crust and especially on one horizon. The carboniferous system, with its huge stores of free carbon, the chief and almost the only resource of the world at present for heat and power, and its hope for the future are to him, a standing enigma. The botanist assures him that all has been extracted from the atmosphere by the agency of green plants, under the stimulus of sunshine. No other process is known whereby this precious element can be severed from its compounds and isolated in free form in any appreciable quantity. Indeed its separation in the laboratory is a somewhat difficult and refined experiment. But this assurance of the botanist darkens rather than clears the enigma of the geologist. Relying with confidence on the botanical principles of his brother-student, which are confirmed by so many concomitant proofs as to be quite unassailable, such as the vegetable structures, leaves, stems and fruits found in the coal, he is yet unable to see where these plants obtained so vast a supply of carbon. From a careful quantitative study of the atmosphere he learns that the sum total of this element therein contained is vastly less than that which now lies buried in the earth, so that to accumulate another stock of mineral fuel equal to that which we are now using so freely and squandering so recklessly, would be an impossibility. The material is not present in the atmosphere, and what is not there can not be taken away. Without troubling you here and now with the calculations, I will merely give sufficient results to establish my statement and to enable you to follow me with confidence. The whole amount of carbon in the air to-day, in the form of carbon-dioxide, does not exceed 150 to 200 cubic miles—a sufficiently large amount, you are ready to say when you try to realize what it expresses. A single cubic mile of coal almost passes comprehension. The world's entire annual con-

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sumption does not exceed 350,000,000 tons, so that one single cubic mile, 7,000,000,000 tons, would suffice to supply us all for twenty years. But the stock of coal and the like, actually in the ground, far exceeds, as I have said, even this enormous figure. To attain anything like exactness in such data is manifestly impossible, but we cannot assign to the world's store of mineral fuel, or the coal contents of our coal fields, oil fields and the like, a less amount than 2,000 cubic miles at the least, or about ten times what could be obtained from the air. Here lies the enigma, and, as you see, the botanist has not furnished any interpretation of it.

It is easy to say, as many have said, that there was a larger supply of carbonic acid in the atmosphere then, than there is now. This is cutting rather than untying the Gordian knot. Perhaps it was so. The explanation is plausible. But the plausible in nature is not always or usually the true.

Time will not allow a full discussion of this topic this evening. It must suffice to indicate, in a general way, the reasons which preclude us from accepting the reply as good and sufficient.

In the first place, let us consider the demand of the geologist. We have mentioned the coal beds, the oil and the gas, but these are far from being all that he requires. There are in the earth huge beds of black shale, holding often from 5 to 15 per cent. of carbonaceous matter. This far exceeds the mass of the coal and we may safely put the figure up from 2,000 to 20,000 cubic miles. Alexander Winchell's total is nearer 30,000. Then the vast stores of peat and the whole animal and vegetable creation, or at least the carbon which they contain, must be included, and this defies exact calculation. Lastly, the mass of coal that has been destroyed by erosion must be added—small though it be beside the vast total. Considering all these it seems perfectly safe to set down the mass of unoxydised carbon in the earth's crust at 50,000 cubic miles, or 250 times as much as that now existing in the air—a proportion of 10 per cent.

Facing this fact the botanist is scarcely willing to admit that plants could flourish in such a medium. Ferns and their allies have been grown in cases charged with an atmosphere containing 10 per cent. of carbonic anhydride, and possibly

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so large a proportion may have been consistent with the existence of the cryptogams of the early eras. Botany cannot give an absolute denial. Experiments on this point are few and not very definite. Prof. Daubeny, of Oxford, stated nearly fifty years ago, in a paper read before the British Association in 1849, that ferns and their allies cannot bear more than 10 per cent., but could exist in an atmosphere containing 5 per cent. of carbon-dioxide. Prof. Boussingault reported, in 1864, that different plants flourish best in atmospheres ranging from 8 per cent. downward. We may therefor infer that the above requirement of the geologist is close to, if not above, the limit of tolerance of plants allied to those by which the mass of our coal was made, and that on this ground it is scarcely tenable.

On the zoological side the evidence is also uncertain. Some of the lower animals, such as fishes and amphibians, are tolerant of a far larger amount of carbon-dioxide than can be endured by the higher groups. But it can scarcely be probable that even they could live in an atmosphere containing as much as 10 per cent.

However, setting aside both these as inconclusive, a physical objection remains to be considered of more serious import. By calculation we find that the conversion of this mass of carbon into carbon-dioxide would absorb all or nearly all the oxygen in the air and leave it devoid of that essential element. We may, therefore, safely assert that whatever the earth's atmosphere may have been in the very early times, the carbon now in the crust cannot have existed as carbonic acid in the atmosphere at any one time since animal life began.

Returning, then, to our former ground we see that, without dogmatizing on the primitive atmosphere, we are unable to accept this plausible explanation as a good and sufficient solution. We cannot hypothecate a sufficient capital stock of carbon to meet the immense and continuous drafts that have been made upon it.

So strongly did one of our most able chemical geologists, the late Dr. Sterry Hunt, feel this difficulty, that he was driven to make the suggestion that the earth had picked up the needed material from the space-realms during her annual and secular journeys—a remark which Alexander Winchell says

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is "highly suggestive." But if we can realize the figures of some modern molecular physicists regarding space we can hardly entertain the suggestion, for they tell us that in the interplanetary regions there is only one molecule of any kind in 10^{814} cubic miles of space. In such an absolute, awful solitude, the earth can surely not have been able to gather up the needed carbon-dioxide, though she had sought it from pre-Cambrian times down to the present day.

But here the microscopist comes upon the field and offers his services in the cause of peace. In diplomatic language, he proposes to act as mediator. He points out, as I have already said, the minute cavities existing in the crystalline rocks and shows that in them is hidden a store of carbonic acid, hoarded, as it were, in the pockets of mother earth, infinitesimally small but infinitely numerous, and he suggests that possibly here a source may be found from which the geologist may get his coal and the botanist his carbonic acid, without alarming the zoologist for the safety of his animals. He shows that on this view it is no longer necessary to assume its presence in the atmosphere all at the same time. Instead of this he suggests that it may have been, and probably was, set free almost atom by atom as the crystalline rocks yielded to erosion and these "sealed flasks" were, one after another, burst open by the pressure within.

At first blush we may be disposed to laugh at the suggestion and to deem such microscopical contributions of small comparative value when so vast a demand is made. But it is well to recollect that "many a little makes a mickle." Let us look at the matter quantitatively for a moment, for here must lie the crucial test. If our theory fails here it fails altogether, though if it pass this test its ultimate success is not hereby assured.

Since the investigation by Mr. Sorby, to which I referred at the outset, little advance has been made until quite recently, when a stimulus was given to new experiments by the marvelous discovery of argon in the atmosphere. The distinguished chemists who were engaged in that most remarkable investigation turned their attention to the gases contained in various minerals, among which were those of the crystalline rocks. And in a paper recently read before the Royal Society

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(March, 1897), Prof. W. A. Tilden stated, as the outcome of some work on quartz, feldspar, and the other constituents of granite, gneiss, gabbro, schist, basalt and other minerals, twenty altogether, from different horizons and widely distant localities, that they all yielded gas in which hydrogen is the preponderating element. Next to hydrogen the most abundant is carbonic acid. And he further makes the important statement that the volume of gas given off by these rocks, and which comes entirely from the minute cavities within them,* ranges from 1.3 to 17.8 times the bulk of the rock; that is to say, that a cubic mile of stone would give out from one to seventeen cubic miles of gas. Considering these figures the problem begins to assume a new aspect and our next question is, How many of these cubic miles of rock have we at command? Because it is evident that if we only have miles enough we can get enough carbon-dioxide.

At this point in the enquiry I was stopped for a while. How is it possible to ascertain the amount that has been worn off the surface of the crystalline rocks since geologic time began? I laid the subject aside for a time. But soon the thought occurred that the mass of the sedimentary rocks, with a few corrections, must equal the amount worn off the crystallines since the days when these latter composed the whole surface. But it is not easy to obtain even this datum and any result must be merely approximate.

I may here be allowed to digress for a moment to explain. All geologists who accept the principle of cosmic evolution (and in the present day few can be found who reject it) are agreed that the earth has cooled and consolidated from an early liquid mass, consisting of slaggy, glassy and stony material resembling modern lavas. From this hard and intractable rock-mass all our sandstones, shales, clays and limestones have been slowly separated by the disintegrating

*As a proof of this fact Prof. Tilden incidentally remarks: "The gas is apparently wholly enclosed in cavities which are visible in thin sections of the rock when viewed under the microscope, but as they are extremely minute, very little gas is lost when the rock is reduced to a coarse powder, and a result of experiment in one or two cases I find that practically the same amount of gas is evolved on heating the rock, whether it is used in small lumps or in powder."

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and dissolving action of water. Over and over again have these strata been broken up and swept away by rains and rivers, until the ancient crystallines have gradually been buried under their own ruins and now occupy comparatively a small part of the surface. None the less has every particle of the sedimentary strata, except carbon and carbon-dioxide, been derived from their steady destruction, the amount of which must, of course, be approximately equal to the mass built up from their ruins.

Had the geologist senses sufficiently exalted he might hear the miniature explosions, as one after another, or, many at the same instant , these little "sealed flasks" burst and discharge their highly compressed contents. In grinding down a thin slice, myriads of them are opened and their gases lost. So in nature, as erosion thins down their crystal walls, these ultimately become so weak that they can no longer withstand the bursting pressure within and a microscopical explosion ensues.

The area of the dry land of the globe equals about 60,000,000 square miles, and by far the greater part of it is covered with thick sheets of sediment. Deduction must be made for the areas where these are absent and the old crystalline rocks still form the surface. But, on the other hand, a large addition is due on account of the sea-margins which for 200 or 300 miles from shore are covered with the wash from the land. With the deep sea I will not here deal.

I assume, then, that one of these corrections will countervail the other and that the area of the sedimentary strata is equal to that of the present dry land or 60,000,000 square miles. Now the thickness of these rocks is very various, ranging from ten miles down to nothing. The former figure is seldom found, but it appears to me that to assume an average depth of one mile is not unreasonable. This will give us for the whole mass eroded from the ancient crystalline rocks the sum of 60,000,000 of cubic miles.

Regarding the quantity of carbon-dioxide contained by the rocks on which Prof. Tilden experimented, the following figures are taken from the report of his paper given in the Chemical News for April 9, 1897:

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		In 100 vols.	
	Vols.	Co_2.	H_2
Tilden. Granite, near Dublin, acid, Plutonic	5.0	9.4	90.6
Granite, Ardshiel, acid, Plutonic	6.9	79.5	20.5
Greisen, Altenburg, Sax., altered, Plutonic	1.8	13.6	86.4
Granulite, India, altered, Plutonic	2.0	48.7	57.3
Quartz-Schist, Co. Down, Metomorphic	2.8	23.0	77.0
Fuchsite Schist, Barodo, Inn., Metamorphic	4.2	20.8	79.2
Corundum rock, Rewah, Ind., Ind., Metamorphic	3.5	26.0	74.0
Pyroxene Gneiss, Ceylon, Metamorphic	7.3	84.4	15.6
Gneiss with Corunbum, Seringapatan, Metamorphic	17.8	18.0	82.0
Gneiss with Garne and Graphite, Ceylon	4.5	11.0	89.0
Gneiss, Himalayas	7.2	11.5	88.5
Dewar and Ansdell. Gneiss	5.3	82.3	13.6
Felspar	1.3	94.7	2.2
	13—79.2	13—522.9	
	5.4	40.	

These results give us an average of five and a half volumes of gas for every volume of rock, and of this quantity 40 per cent. was carbon-dioxide. Combining the averages we find that these Archean minerals yielded between two and three times their volume of carbon-dioxide. Combining again with the previous result—60,000,000 cubic miles of eroded crystalline rock—we obtain about 150,000,000 cubic miles of gas. Of this the three-thousandth part will be carbon in the solid form.

In this way the final result is reached; that by these minute contributions we get about 50,000 cubic miles of carbon, equal to at least 60,000 cubic miles of coal. As the total stock of existing coal amounts to only about 2,000 cubic miles, or with all the other forms of unoxydised carbon, to not more than 50,000 cubic miles, we have a supply ample and more than ample for the demand.

In such an investigation I need not caution anyone against laying much stress on the exact figures here given. A calculation when the data are so indefinite can but be approximate. Yet I hope I have shown that allowing for all inaccuracy we have here a supply of the precious element, carbon, from which the geologist can obtain his coal without offending his brethren, the botanist and the geologist, by insisting upon a greater amount at any time in the atmosphere than they are

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willing to allow. Here we have a supply from which it can be drawn as wanted without disturbing the existing balance of atmospheric composition, or compelling us to assume that in the early days of life the air was materially different from what it is at the present time.

I am sure it must be interesting to the working members of the American Microscopical Society to see how the investigation of these minute bubbles in the crystalline rocks leads on to the discovery of a possible origin of the carbon in our coal. To any geologists present I must excuse myself for considering only part of the problem and saying nothing of the other stores of this carbonic acid in the rocks of the earth compared with which the coal and other free carbon in the earth is a mere vanishing quantity. But the conditions differ and the solution of that problem must differ also.

The unconsidered elements would, if introduced, vastly and unduly extend this discussion, while they would not in any way conflict with what I have said. They would complicate, but not invalidate the argument. I have merely endeavored to put forward and maintain a mechanism whereby carbon-dioxide could be obtained as wanted by the plant-world without charging the atmosphere with the whole amount at once.* I have shown how the deposit in the atmospheric bank can be obtained through the receiving teller while the paying teller is constantly releasing it in response to checks on demand.

Meanwhile I have given you a glimpse down some of the long vistas of geologic time. I have brought before you some of the processes of world making—some actual records of æons long gone by—some relics of remote conditions entombed when time was young. You have in imagination, seen the glowing lithosphere slowly cooling and crystallizing and as the solid earth was built there were stored in its foundation stones these samples of its primeval atmosphere, sealed

*An interesting possibility—I may say, from some points of view, a probability--would lead us too far here, if we were to attempt its discussion. But there is nothing unlikely in the supposition that the whole oxygen of the atmosphere has been set free from its combination in the form of carbon-oxide by the action of plant-life. Such a supposition is beset with some difficulties, not, perhaps, insuperable, but it has many strong reasons in its favor.

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in their crystal flasklets. The building advances, the cooling nucleus contracts, the cold and solid crust outside, being unsupported, sinks and is crushed. You hear, as it were, the creaking of the massive globe as its crystalline particles yield before the inconceivable earth-force. Then—in that time, not of disaster and catastrophe, but of slow, imperceptible evolution—were graven on stone those mystic characters which the microscope has interpreted to you this evening.

[Contributions to the Mineralogy of Minnesota. I.]

NOTE ON THE CHARACTERS OF MESOLITE FROM MINNESOTA.*

By N. H. Winchell, Minneapolis, Minn.

Mesolite. The most conspicuous, and the most collected of all the Minnesota zeolites is mesolite. It has been widely distributed from Grand Marais and from other points west from Grand Marais, under the name thomsonite. Some of the specimens collected by the State Geological Survey in 1877 and 1878 were examined by Peckham and Hall (Am. Jour. Sci. XIX, 122, 1880), and from chemical characters were considered thomsonite and that designation has been followed by the survey in all later reports. This mineral is usually white, but varies from white to pink and to green, these colors alternating in superficial bands forming colored circlets or rosettes which with its hardness have rendered this mineral a gem of considerable beauty and value.

It is strongly radiated in fine fibres, which are long and rigid, in this respect differing from thomsonite, whose fibres are coarser and somewhat irregular in direction and shape. Specific gravity is 2.26.

Optic Characters. Sections cut perpendicular to the fibres give the greatest light. Those parallel to the fibres are sometimes almost invisible in certain positions, especially in sections rather thin, owing to the very low power of

*This and other examinations of the rocks and minerals of Minnesota were done primarily in the laboratory of Prof. A. Lacroix, Museum d'Histoire Naturelle, Paris, and with his assistance, for which the writer wishes to testify his gratitude.

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double refraction. These contrasts are sometimes strongly brought out. For instance: in a section cut about parallel with a lot of fibres the general obscurity of the field may be relieved by scattered rhombs of very light and bright aspect, whose perfect forms are bounded by right lines and which occur sometimes in regular succession across the field of the microscope. Such rhombs are sometimes nearly square, but may also become much elongated in the direction of their greater axes. As they become longer they also become darker, and finally by continuing their elongation they blend into the general structure and disappear in the fibrous mass in which they lie. In other words, the fibres that happen to be cut obliquely, or perpendicularly, give more light than those that are cut parallel. This only shows that the plane of the optic axes is perpedicular to the elongation of the fibres. The same fact can be shown by the use of a section cut parallel to the fibres, by the application of the quartz of sensitive tint, when it will be seen that some are red and some are blue, although lying adjacent, i. e. some have n_g perpendicular and a negative elongation, and others have n_p perpendicular with a positive elongation.

Chemically, mesolite is quite similar to thomsonite, being a silicate of alumina, lime and soda, with about 12 per cent. of water. If the specimen be somewhat altered by weathering, and if at the same time thomsonite and mesolite be intimately ingrown, as sometimes happens, it is evident that the result of a chemical analysis would be a poor basis on which to name the specimen.

The optic angle in mesolite is large, and in thomsonite it is small. This difference introduces another evident optical character by which the two minerals can be distinguished: viz. sections of mesolite cut parallel to the fibres are almost uniformly illuminated whether they present n_p or n_g perpendicularly, the amount of light along those axes being about the same; but a section or thomsonite cut in the same way will exhibit certain fibres that are much lighter than the others. Thus quite light and quite dark fibres may alternate, or they may occur in bundles. The light fibres are cut perpendicular to n_p in the greater optic angle and have positive elongation, while the dark fibres are cut perpendicular to n_g in the optic angle and have negative elongation.

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Still, the chief and most marked optic character distinguishing this mineral from thomsonite is its much lower double refraction. This mineral never shows colors, between crossed nicols, in a section of ordinary thinness for microscopical purposes, even when cut parallel to the optic plane, while thomsonite uniformly rises into red, and to blue of the second order, in sections of .03 mm thickness.

Localities. The most celebrated localities are at Terrace Point, which encloses Good Harbor bay, a few miles west of Grand Marais, and thence westward to Poplar river. It is frequently seen as waterworn pebbles in the gravel of the beach. It occurs at Lover's bay, at Gooseberry River falls, at Pork bay, Beaver bay and Agate bay. It is evidently a product of alteration of labradorite in the coarse diabases and gabbros. As such it occurs plainly at the east point of Sucker bay (90B) where it results from a change in labradorite. The most remarkable instances of such alteration occur at Carlton's peak, as discovered by Mr. A. H. Elftman. Here the anorthosyte holds nests of radiated fibres of mesolite as large as two or three inches in diameter.

[European and American Glacial Geology Compared. IX.]

GLACIAL RIVERS AND LAKES IN SWEDEN.

By WARREN UPHAM, St. Paul, Minn.

Among the several European countries through which our travel last year extended, none was geologically more interesting to me than Sweden, because it affords very instructive comparisons with my earliest and latest geologic studies in America, first, on the origin of kames and eskers in New Hampshire,* and, last, on the glacial lake Agassiz,† in the basin of the present lake Winnipeg. In the same year (1876)

*Proc. A. A. A. S., XXV, for 1876, pp. 216-225. Geology of N. H. vol. III, 1878.

†Geol. and Nat. Hist. Survey of Minnesota, Eighth Annual Report, for 1879, pp. 84-90; Eleventh Rep., for 1882, pp. 137-153, with map; Final Report, vols. I (1884) and II (1888). Geol. Survey of Canada. Annual Report, new series, vol. IV, for 1888-89, Part E, 156 pp. with maps and sections. U. S. Geol. Survey, Monograph XXV, 1896, 658 pp., with 38 plates and 35 figures in the text.

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when my earliest geological paper was published, Dr. N. O. Holst, of the Geological Survey of Sweden, presented a closely similar theory to explain the formation of the eskers (åsar) of that country.* We then were wholly unacquainted with each other, our conclusions, and the nearly similar earlier suggestion of Prof. N. H. Winchell on the same subject,† having been in each case reached quite independently. Afterward, in the recognition and mapping of glacial lakes, held by the barrier of waning ice-sheets, the first example in America somewhat completely traced and defined was the small lake Contoocook in the valley of the Contoocook river in New Hampshire, which I discovered while working under the direction of Prof. C. H. Hitchcock in the survey of that state. Within the subsequent twenty years the very large glacial lakes of the St. Lawrence basin, which before were partially defined by Newberry, N. H. Winchell, and others, have become more fully known by the explorations of Gilbert, Spencer, Taylor, Lawson, Leverett, and others, including the present writer; and the largest lake of this class, first recognized in 1872 as a glacial lake by Winchell, and named by me in 1879 in honor of Louis Agassiz, I have specially mapped and described under the auspices of the geological surveys of Minnesota, the United States, and Canada. It was therefore a chief purpose in my travel through Sweden to observe and learn as much as possible concerning its hundreds of eskers, the ice-walled deposits of glacial rivers, and its scores of identified glacial lakes that were pent up in the valleys between the western side of the departing European ice-sheet and the mountainous Scandinavian watershed.

In its maximum extension, this ice-sheet, reaching outward from Scandinavia to London, Brussels, Dresden, Cracow, Kief, and Nijni Novgorod, covered an area of about 2,000,000 square miles, including the basins of the Irish, North, Baltic, and White seas. Later its diminished extent, when it had considerably retreated, is marked by the morainic Mecklenburg or Baltic ridge, its continuation in Denmark to Frederikshavn and the northwest coast, and, as I think, its far-

*"Om de Glaciala Rullstensasarne," Geologiska Föreningens i Stockholm Förhandlingar, No. 31 (vol. III, pp. 97-112).

†Geol. and Nat. Hist. Survey of Minn., First Annual Report, for 1872, p. 62.

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ther course to the shoals of the Dogger bank in the North sea and to the Flamborough moraine on the northeast coast of England.* Still later, this vast ice-sheet gradually decreased, forming marginal moraines at various stages of its recession, until it was finally melted from the greater part of Norway and from southern Sweden but remained on a large central part of Sweden, where it had been accumulated thickest. The ice surface there, during the culmination of the Glacial period, had doubtless surpassed in altitude the highest mountains of this peninsula, and its westward outflow from that area of ice-shed had carried many Swedish boulders over the mountain passes into Norway. It is very probable, too, that during the departure of this latest remnant of the European ice-sheet its axial tract of greatest though diminishing thickness moved somewhat farther eastward, on account of the generally eastward course of storms of rain and snow, as was apparently true of the Minnesota lobe of the North American ice-sheet and of its more eastern part which was the barrier of the Laurentian glacial lakes. The Swedish eskers and shorelines and deltas of glacial lakes preserve for us very abundant records of the glacial recession in this part of Europe, enabling the explorer to follow the waning ice borders to the latest tract upon which they opposed the drainage of the present river valleys.

Within the cities of Stockholm and Upsala, and in their near environs, I saw admirable new sections of the eskers which are named from these cities, prolonged and massive ridges of gravel and sand, much exceeding, in magnitude of development, the eskers of Ireland and Great Britain, but equalled or surpassed by the eskers of Maine, described by Prof. George H. Stone, and by those surveyed and mapped by me in New Hampshire. On large areas of southern Sweden these very remarkable ridges of the coarsest modified drift run in many nearly parallel southerly courses and on either side receive tributaries from the north, so that as to parallelism in their mapping they resemble the abundant river courses of Virginia and the Carolinas, of eastern Iowa, or of Nebraska, Kansas, the Indian Territory, and Texas. A sec-

*See the sixth paper of this series. Am. Geologist, XXII, 43-49, July, 1898.

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tion of the Upsala esker, reproduced from a photograph, is published by Sir Henry H. Howorth in one of his most recent papers,* with denial of the agency of an ice-sheet for its origin; but if his opinions in this matter receive any credence among European geologists, they are less agreed than in the United States, where, as Fairchild well said in his recent American Association address, the glacial origin of the drift has passed beyond the condition of a theory to that of a fully demonstrated and generally accepted fact. The work of Stone on the eskers and other associated modified drift of Maine, partly published in his earlier papers and more elaborately written for publication as a monograph of the United States Geological Survey, should be well studied by geologists in Europe, when such theories as the debacle explanation of the origin of eskers and other drift formations are still acceptable in their technical journals of our science.

Eskers are rare in Norway. One of their few notable localities in that country, and the only one that I observed, is at Röros, 247 miles north of Christiania on the railway to Trondhjem, and 2,060 feet above the sea. There an excellent example of an esker series, in part compound, has an extent of two miles, or more, from northwest to southeast, and rises 75 to 125 feet above the adjoining land, being on the east side of the Glommen valley near its head. The gravel includes cobbles up to one or rarely two feet in diameter. From the courses of glacial striation in the region, it is known that the recession of the ice there was toward the southeast, the drainage from Röros having passed northward to the Gula valley, over a col crossed by the railway several miles farther north, at 2,200 feet above the sea.

After the waning ice-sheet had relinquished nearly all of Norway, remaining only on a narrow central tract in the wide southern part of that country, and thence extending with increasing breadth to northern Sweden, its obstruction across the heads of valleys that sloped down toward the northwest side of the receding ice caused them to contain glacially dammed lakes. Some of these lakes have been partly explored and mapped, so far as the mostly wooded and only sparsely

*Geol. Magazine, Decade IV, vol. V, pp. 195-206 and 257-266, May and June, 1898.

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inhabited condition of the country permits, by Andrew M. Hansen in the part of Norway southeast of the main watershed of the peninsula, and by Gunnar Andersson upon an area of a hundred miles extent from south to north in Jemtland, Sweden.

Hansen notes the altitude of the Norwegian glacial lakes as ranging from 2,150 to 3,575 feet above the sea level, these hights being known by the cols of the mountain belt through which they outflowed; and their lengths, extending as the ice retreated, became for the larger lakes, according to Hansen, almost a hundred miles, with depths of about 1,000 feet.*

The region of the old glacial lakes described by Andersson† is traversed by the railway leading from Trondhjem east and south to Stockholm upon a distance of a hundred miles, from Ånnsjön (Ånn lake) past the Storsjön (Great lake), to Östersund and Pilgrimstad. The Ånnissjön (Ånn glacial or "ice" lake) and the Kallissjön of Andersson, outflowing through passes of the western watershed, are marked over large tracts of mountain-inclosed valleys by shore erosion and beach deposits and by delta terraces, at the hights, respectively, of about 1,830 and 1,500 feet; and the later and considerably larger Näldissjön, which extended over the present area of the Storsjön, attained the size of about 1,700 square miles, its altitude, determined by a lower outlet, being about 1,350 feet above the sea. The shorelines and deltas of these glacial lakes appear to be as well developed in many places as the parallel roads of Glen Roy or the beaches of lake Agassiz. The general prevalence of forests, however, forbids tracing the shores for long distances. When this shall be done at any future time, it seems probable that the planes of the old lakes will be found to have undergone differential changes of level in the Postglacial uplift which is known to have affected the whole country, although little indication of this is given by Andersson's maps. It is further to be remarked, also, that the recession of the ice border could hardly have been so uniform on this large district as these maps would denote; but

*Nature, vol. XXXIII, 1886, pp. 268, 365.

†Geol. Survey of Sweden, Series C, No. 166, "Den Centraljämtska Issjön," 38 pages, with 8 figures in the text and 3 maps, 1897.

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they are a good incentive for more detailed explorations, with sufficient determinations of altitudes by levelling.

It would be highly interesting if the rate of final recession of the ice-sheets of North America and Europe upon any parts of their areas can be ascertained. The most definite testimony given on this question by drift deposits in any locality known to me was pointed out by Baron Gerard De Geer in a short excursion on which he guided me to a series of morainelets, if this term may be used, situated on a tract about three miles long from east to west and one to two miles wide, lying next west of the little railway station of Sundbyberg, which is three miles northwest of Stockholm. Each morainelet there is from 5 to 15 rods wide, and from 5 to 25 feet high above the adjoining surface, which consists of level cultivated fields of marine clay, excepting frequent exposures of the granitic bedrocks, moutonnéed, which are bare on considerable spaces, having no drift nor boulders, strongly in contrast with the drift knolls and small ridges of the morainelets, encumbered with their abundant boulders up to 10 feet or sometimes 20 feet in diameter. These little moraines, approximately parallel and traceable more or less continuously from east to west, occur to the number of eight or ten on the width of about a mile. If they represent successive years of the glacial retreat, as De Geer thinks, it had there a rate of about a hundred miles in a thousand years, which would agree in a general way with the duration of the Champlain or closing epoch of the Ice age as estimated from other lines of investigation on both these continents.

One of the special inquiries which Baron De Geer is now prosecuting relates to the possible correlation of the intervals between these morainelets with the probably annual layers of clay deposition attendant on the withdrawal of the ice-sheet, observed at many places in southern Sweden nearly as at Chaska, Carver, and Jordan, in the Minnesota river valley. With these apparently annual glacial records, he also thinks that an additional correlation may be afforded by the successive knolls, widening, or changes in coarseness of material, which many eskers display at short intervals of their course.

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REVIEW OF RECENT GEOLOGICAL LITERATURE.

Ueber die Verbreitung der Euloma-Niobe-Fauna (der Ceratopygi kalk fauna) in Europa, Von PROF. DR. W. C. BROGGER Nyt Mag. for Naturvidensk, B. XXXV, S. 164-240, Christiania, 1896.

This is a remarkably comprehensive essay treating of the borderland between the Cambrian and Ordovician systems. Dr. Brögger takes up in turn the various regions where the fauna of the Ceratopygi limestone (for which he prefers the name Euloma-Niobe Fauna) has been found and compares the forms of this fauna with each other. In many cases the close resemblance of these regional faunas has not been evident because the forms have been ranged under different genera by the several authors who have described them. Dr. Brögger correlates these forms with a master hand and makes a strong plea for the point he urges, namely the relation of this fauna to the Ordovician system. He first revises the fauna in Languedoc described by Munier-Chalmas and Bergeron as follows:

Calymenopsis filacovi becomes Euloma filacovi.

Dictyokephalites villebruni becomes Harpides villebruni.

Amphion escoti is compared to Amphion primigenus Ang.

Ogygia ligniersi Berg. becomes Niobe ligniersi.

Eglina sicardi Berg. becomes Symphysurus sicardi.

Asaphelina miqueli Berg. represents a new genus.

Asaphelina barroisi M-C & B, becomes Dicelocephalina barroisi.

Megalaspis filacovi equals Megalaspides? (s. gen.) filacovi etc.

It has long been known that Salter's old names for the genera of the Trunadoc slates needed revision and no abler paleontologist than Dr. Brögger could have undertaken the task. As a result of his examination we find the following presentation of the genera:

Niobe homfragi is compared to N. nisignis Linrs.

Platypeltis and Psilokephalus (2 species) is compared to Symphysurus incipiens Brögg.

Ampyx parnuntius is compared to A. domatus Ang.

Dikelokephalus furca is compared to Dikelokephalina dicraura Ang.

Angelina sedgwickii is compared to Parabohinella limitis Brögg.

Conocoryphe, 2 species, is compared to Cyclognathus micropygus Linrs.

Agnostus dux is compared to Agnostus sidenbladhi Linrs.

Conocoryphe invitus is compared to Apatokephalus serratus Boeck.

C. monile is compared to Euloma ornatum.

C. abditum is compared to Euloma ornatum.

The faunas of Bavaria, of Bohemia, of North America and other regions, of this age, are similarly treated, and much light thrown upon the relations of the old genera and the species found in these respective countries.

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The main object of Dr. Brögger's paper is to show that these types form a well characterized fauna which he calls the Euloma-Niobe fauna and which he says should be separated from the Cambrian and united to the Ordovician faunas, chiefly because the majority of the genera have an affinity for the genera of the latter system, and that comparatively few of the trilobites resemble those of the Cambrian system. At the first blush there would seem to be much to recommend this view, but a similar argument applied to the lower paleozoic deposit of the Atlantic border region in North America would sweep even the Arenig or Tetragraptus horizon into the Cambrian as the Ceratopygi fauna is wanting and *the Cambrian types of trilobites are the only ones found even in the Tetragraptus beds.* The question of the assignment of the Euloma-Niobe fauna is not therefore vital in this region, but if it prove of more importance than that already adopted as the base of the Ordovician, viz: the Tetragraptus Fauna, it should be adopted; a change however would involve the re-arrangement of the collections in many museums as the fauna is now made a very comprehensive one.

The article is accompanied by two page illustrations showing the types of the new sub-genera Dikokephalina and Apatokephalus and a table showing Dr. Brögger's view of the proper generic reference of seventy species of the European forms of this fauna. This article, though dated April, 1896, was not received until the summer of 1898.

G. F. M.

Occurrence of Fossil Fishes in the Devonian of Iowa. By CHAS. R. EASTMAN. Iowa Geol. Sur., Vol. VII, pp. 473-488, 1898.

A generation ago great activity was shown in the collection of the fossil fishes of the Mississippi valley. The wonderful variety of forms, and the marvelous abundance of remains excited the interest of every paleontologist. The labors of Newberry, St. John and Worthen will long be remembered. For more than a score of years, however, the subject has been allowed to drop almost out of sight, for during this period practically nothing has been done to advance our knowledge along this line.

It is, then, with no small degree of pleasure that the recent revival of the interest in the old ichthyic faunas has been noted. Under the auspices of the Museum of Comparative Zoology, of Cambridge, Dr. Charles R. Eastman has, during the past three years energetically set to work to get together all the accumulated fish remains from the American Paleozoic, and to study them carefully in the light of the latest discoveries. His critical papers, giving the results of some of his special investigations, as a part and preliminary to a greater undertaking, which is always kept in mind, have appeared with a frequency and regularity that betokens great enthusiasm, energy and thoroughness.

Of the latest contributions that have been issued none is more instructive than that on the fossil fishes from the Devonian of Iowa.

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This memoir is the first of a series dealing with the relationship of the Devonian and Carboniferous fish faunas. The key-note to their consideration is contained in the opening paragraphs of Dr. Eastman's paper, when he says: "The fish faunas of the Devonian and Carboniferous systems present such marked differences as in a measure to justify the assertion that a great revolution in ichthyic development took place towards the close of the former period. During the Devonian, the fishes commonly known as Placoderms greatly preponderated over the Elasmobranchs, which continued to hold a subordinate position, both relatively and absolutely, from the date of their initiation onward. But with the extinction of the Placoderms at the close of the Devonian, the Elasmobranchs entered upon a new era of development, increasing prodigiously in point of numbers and variety, attaining great size, and becoming more formidably armed. In contrast with the remarkable dearth of Elasmobranchs in the Silurian and Devonian, upwards of 600 species have been described from the Carboniferous of this country and Europe; and it is probable that this group of fishes was much more abundant during the Carboniferous than at present or during any other geologic period."

The account of the Iowa fishes brings into prominence a newly discovered fauna from the upper Devonian. It was obtained by professor Calvin from the old state quarries, near North Liberty. "Some of the teeth bear such close resemblance to those of Carboniferous sharks that they were first mistaken for them or their allies; but with the acquisition of a larger amount of material very remarkable transitions were observed between them and undoubted Dipterid species."

Incidentally the paper has a direct bearing upon the problem presented by the typical Kinderhook beds of Illinois and Missouri. The note records that "An unfinished manuscript lately discovered among the effects of professor Newberry, and to be issued as a posthumous publication under the editorship of Mr. Bashford Dean, contains descriptions of two new species of Dipterus from the Chemung group of Pennsylvania. Mr. Dean was kind enough to compare the originals with photographs of the new Iowa species, and pronounces them distinct. The same manuscript also mentions the occurrence of Ptyctodus teeth in the so-called "Kinderhook beds" of Louisiana, Missouri; and it is stated that no differences can be detected between them and the well-known P. calceolus, which is limited to rocks of Devonian age. This is important, for it furnishes additional confirmation of the view contended for, by Calvin and Keyes, that a part of the formation at Louisiana is unquestionably Devonian."

In conclusion Dr. Eastman observes that it is "apparent that we have here to deal with a unique and highly interesting assemblage of fossil fishes. A number of new Dipnoan genera are encountered, some of which present astonishing resemblance to primeval sharks, and others are connected by gradual transitions with Dipterus. Careful study of these forms can hardly fail to clear up many difficult problems affecting Paleozoic fishes. The presence of Dipterus and Arthrodires

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brings the Iowa fauna into relationship with the Chemung and Catskill of Pennsylvania on the one hand, and with the Waverly of Ohio on the other. Nevertheless the different aspects of these faunas when compared with one another are very considerable. Through Ptyctodus calceolus the fauna is related also to the Hamilton of the Mississippi valley. The abundance of this form, and the absence of all other Elasmobranchs is a surprising circumstance. However, it is more than likely that further search will bring to light many forms which we should naturally expect to find in rocks of this horizon."

Some of the further descriptions of the Iowa fishes are contained in an article by Dr. Eastman, in the American Naturalist for July, 1898 (vol. XXXII, pp. 473-488) in which is considered the Dentition of the Devonian Ptyctodontidæ. "Three genera of Paleozoic Chimæroids, known only by remains of this dentition, constitute the, at present, imperfectly definable family Ptyctodontidæ. These are Ptyctodus, Rhynchodus and Palæomylus, distributed throughout the middle and upper Devonian of northern Europe and North America. The 'jaws,' or dental plates as they are more properly called, are rarely well preserved, and invariably occur in the detached condition."

While the bulk of a large amount of the new material came from the state quarries of Iowa, important collections were obtained near Milwaukee, Wisconsin. C. R. K.

Geological Survey of New Jersey, Annual Report of the State Geologist [PROF. JOHN C. SMOCK] *for the year 1897*. Pages xl and 368, with 13 plates, and 25 figures in the text; Trenton, 1898.

The administrative report, 28 pages, concisely noting the year's work, is followed by reports of progress, on the surface geology, by Prof. Rollin D. Salisbury, in 22 pages, with a preliminary map of the surface formations of the state; on the Newark system or Red Sandstone belt, by Dr. Henry B. Kümmel, in 137 pages, with a map and eight other plates; on the Upper Cretaceous formations, by Prof. William B. Clark, in 50 pages; on artesian wells, by Lewis Woolman, 85 pages; on the drainage of the Hackensack and Newark tide-marshes, by C. C. Vermeule, 19 pages, with three plates; and supplemental notes on the mining industry, by George E. Jenkins, 41 pages.

Professor Salisbury revises his former nomenclature of the surface deposits south of the glacial drift area. The Beacon Hill formation remains of undecided age, late Miocene, or subsequent. The name Bridgeton formation is proposed for the early part what was formerly called the Pensauken, this name being still retained for the later part; the Bridgeton beds are regarded as the probable equivalent of the Lafayette; and the Pensauken beds, under their restricted definition, as correlative with the early Albertan or Kansan glaciation. Another new term, the Cape May formation, is proposed for the deposits of Late Glacial and Early Postglacial age in the region south of the direct effects of the ice-sheet and its drainage. This formation includes the later part of what Prof. Salisbury has before called the Jamesburg formation; and its earlier part, which is less distinctly developed, is neglected in the present mapping.

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The detailed examination of the Newark system in New Jersey has been completed, and is quite fully reported; but it is hoped to present later a more elaborate discussion of some of its problems when explorations have been extended for comparison beyond the limits of this state.

Professor Clark contributes a very interesting summary of the investigations of the Upper Cretaceous series, as studied by himself and his associates during the past five years in New Jersey, Maryland, and Delaware, preceded by a history of the work of former observers. W. U.

Iowa Geological Survey, Volume VIII: Annual Report, 1897, with Accompanying Papers. SAMUEL CALVIN, State Geologist; H. F. BAIN, Assistant State Geologist. 427 pages, with 32 plates, 13 figures in the text, and six folded geological maps; Des Moines, 1898.

This volume comprises administrative reports which give brief statements of the progress of the survey last year, with a summary of the condition and statistics of production of the mining industries and quarrying in the state during the year. The aggregate value of the mineral production was nearly seven and a half million dollars. Following these reports are papers on the geology of Dallas county, by A. G. Leonard; of Delaware and Buchanan counties by Prof. Calvin; and of Decatur and Plymouth counties, and on Properties and Tests of Iowa Building Stones, by H. Foster Bain.

In Buchanan, Decatur and Plymouth counties, exceptionally interesting problems have been studied concerning the sequence of stages or epochs of the Glacial period. The last named county and adjoining parts of northwestern Iowa are found to present difficulties in correlating the successive drift sheets and loess deposits with those of other parts of the state. The evidence perhaps indicates that northwestward, in the Missouri river basin, the deposition of the loess continued from the time of recession of the ice border at the end of the Iowan stage until the time of formation of the Altamont moraine on the margin of the ensuing Wisconsin stage of glaciation. The Iowan and Wisconsin stages probably occurred very near together; but they were far later than the even more closely consecutive Kansan and Buchanan stages, which were doubtless several times longer ago than the Iowan glacial readvance. W. U.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Bain, H. F.

Geology of Decatur county [Iowa]. (Iowa Geol. Survey, vol. 8 pp. 255-309, pls. 21-24, 1 map, 1898.)

*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

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Bain, H. F.

The Aftonian and pre-Kansan deposits in southwestern Iowa. (Interglacial deposits in Iowa: A symposium presented at the Iowa Academy of Sciences, Des Moines, Iowa, Dec. 28, 1897; pp. 23-38, 1 map, 3 pls. Reprinted from Proc. Iowa Acad. Sci., vol. 5, 1898.)

Bain, H. F.

Geology of Plymouth county [Iowa]. (Iowa Geol. Survey, vol. 8, pp. 315-366, pls. 25-29, 1 map, 1898.)

Bain, H. F.

Properties and tests of Iowa building stones. (Iowa Geol. Survey, vol. 8, pp. 367-416, pls. 30-32, 1898.)

Bishop, I. P.

The structure and economic geology of Erie county [New York]. (15th Ann. Rept. State Geol. of New York, pp. 305-392, 16 pls. 6 maps, 1897.)

Butts, Edward.

Description of some new species of crinoids from the Upper Coal Measures of the Carboniferous age at Kansas City, Missouri. (Trans. Acad. Sci. of Kansas City, vol. 1, pp. 13-15, Apr. 12, 1898.)

Calvin, Samuel.

The interglacial deposits of northeastern Iowa. (Interglacial deposits in Iowa: A symposium presented at the Iowa Academy of Sciences, Des Moines, Iowa, Dec. 28, 1897; pp. 1-7. Reprinted from Proc. Iowa Acad. Sci., vol. 5, 1898.)

Calvin, Samuel.

Geology of Delaware county [Iowa]. (Iowa Geol. Survey, vol. 8, pp. 119-192, pls. 7-13, 1 map, 1898.)

Calvin, Samuel.

Geology of Buchanan county [Iowa]. (Iowa Geol. Survey, vol. 8, pp. 201-253, pls. 14-20, 1 map, 1898.)

Case, E. C.

The development and geological relations of the vertebrates. Pt. II. Amphibia. Pt. III. Reptilia. (Jour. Geol. vol. 6, pp. 500-523, July-Aug., 1898.)

Chamberlin, T. C.

The ulterior basis of time divisions and the classification of geologic history. (Jour. Geol. vol. 6, pp. 449-462, July-Aug., 1898.)

Clarke, J. M.

The stratigraphic and faunal relations of the Oneota sandstones and shales, the Ithaca and Portage groups in central New York. (15th Ann. Rept. State Geol. of New York, pp. 27-81, 7 pls, 2 maps, 1897.)

Clarke, J. M.

Notes on some crustaceans from the Chemung group of New York. (15th Ann. Rept. State Geol. of New York, pp. 729-738, 1897.)

Cushing, H. P.

Report on the geology of Clinton county [New York]. (15th Ann. Rept. State Geol. of New York, pp. 499-573, 5 pls., 1897.)

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Eastman, C. R.

Dentition of Devonian Ptyctodontidæ. (Am. Nat., vol. 32, pp. 545-560, Aug., 1898.)

Elftman, A. H.

The geology of the Keweenawan area in northeasten Minnesota. III. (Am. Geol., vol. 22, pp. 131-149, pl. 7, Sept. 1898.)

Emmons, F. H., and G. W. Tower, Jr.

Economic geology of the Butte special district. (U. S. Geol Survey, Geologic Atlas of the U. S., folio 38, Butte special folio, 6 pp., 3 maps, 1897.)

Fairchild, H. L.

Glacial geology in America. (Am. Geol., vol. 22, pp. 154-189. Sept. 1898.)

Finch, J. W.

The basal portions of a continental glacier. A dissertation submitted to the faculty of Colgate University in candidacy for the degree of Master of Arts. (Pp. 1-38; The University Press, Hamilton, N. Y., 1898.)

Gilpin, E. Jr.

Ores of Nova Scotia. Gold, lead, and copper. (Pp. 1-46, 1 map; Commissioner of Public Works and Mines, Queen's Printer, Halifax, 1898.)

Goodwin, W. L.

Analyses of corundum and corundum-bearing rock. (Rept. Bureau of Mines of Ontario, vol. 7. pt. 3, pp. 238-239, 1898.)

Gordon, C. H.

Notes on the Kalamazoo and other old glacial outlets in southern Michigan. (Jour. Geol., vol. 6, pp. 477-482, pl. 12, July-Aug., 1898.)

Gracey, A. H.

Placer gold on Vermilion river [Ontario]. (Rept. Bureau of Mines of Ontario, vol 7, pt. 3, pp. 256-259, 1 map, 1898.)

Hay, O. P.

Notes on species of Ichthyodectes, including the new species I. cruentus, and on the related and herein established genus Gillicus. (Am. Jour. Sci., ser. 4, vol. 6, pp. 225-232, Sept. 1898.)

Hillebrand, W. F.

Distribution and quantitive occurrence of vanadium and molybdenum in the rocks of the United States. (Am. Jour. Sci., ser. 4, vol. 6, pp. 209-216, Sept., 1898.)

Jefferson, M. S. W.

The postglacial Connecticut at Turners Falls, Mass. (Jour. Geol., vol. 6, pp. 463-472, July-Aug., 1898.)

Kemp, J. F.

Preliminary report on the geology of Essex county [New York]. (15th Ann. Rept. State Geol. of New York, pp. 575-614, 12 pls., 1897.)

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Leonard, A. G.

Geology of Dallas county [Iowa]. (Iowa Geol Survey, vol. 8, pp. 51-118, pls. 4-6, 2 maps, 1898.)

Leverett, Frank.

The weathered zone (Sangamon) between the Iowan loess and Illinoian till sheet. (Interglacial deposits in Iowa: A symposium presented at the Iowa Academy of Sciences, Des Moines, Iowa, Dec. 28, 1898; pp. 8-17, 1 map, 1 pl. Reprinted from Proc. Iowa Acad. Sci., vol. 5, 1898.)

Leverett, Frank.

The weathered zone (Yarmouth) between the Illinoian and Kansan till sheets. (Interglacial deposits in Iowa: A symposium presented at the Iowa Academy of Sciences, Des Moines, Iowa, Dec. 28, 1897; pp. 18-23. Reprinted from Proc. Iowa Acad. Sci., vol. 5., 1898.)

Luther, D. D.

The stratigraphic position of the Portage sandstones in the Naples valley and the adjoining region. (15th Ann. Rept. State Geol. of New York, pp. 233-236, 1 pl., 1 map, 1897.)

Luther, D. D.

The economic geology of Onondaga county, New York. (15th Ann. Rept. State Geol. of New York, pp. 237-303, 20 pls., 2 maps, 1897.)

Martin, G. C.

An occurrence of dunite in western Massachusetts. (Am. Jour. Sci., ser. 4, vol. 6, pp. 244-248, Sept. 1898.)

Miller, W. G.

Economic geology of eastern Ontario. Corundum and other minerals. (Rept. Bureau of Mines of Ontario, vol. 7, pt. 3, pp. 207-238, 6 pls., 1 map, 1898.)

Moses, A. J.

An introduction to the study and experimental determination of the characters of crystals. Chap. XI. (School of Mines Quarterly, vol. 19, pp. 374-391, July, 1898.)

Packard, A. S.

A half-century of evolution, with special reference to the effects of geological changes on animal life. (Science, new ser., vol. 8, pp. 243-257, Aug. 26, 1898; pp. 285-294, Sept. 2, 1898; pp. 316-323, Sept. 9, 1898.)

Reid, H. F.

The variations of glaciers. III. (Jour. Geol., vol. 6, pp. 473-476, July-Aug., 1898.)

Ries, Heinrich.

Physical tests of the Devonian shales of New York state to determine their value for the manufacture of clay products. (15th Ann. Rept. State Geol. of New York, pp. 673-698, 1897.)

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Ries, Heinrich.

Geology of Orange county [New York]. (15th Ann. Rept. State Geol. of New York, pp. 393-475, 42 pls., 1 map, 1897.)

Spencer, J. W.

Geological water ways across Central America. (Appleton's Pop. Sci. Monthly, vol. 53, pp. 577-593, Sept. 1898.)

Smyth, C. H. Jr.

Report on the crystalline rocks of St. Lawrence county [New York]. (15th Ann. Rept. State Geol. of New York, pp. 477-497, 1897.)

Smyth, C. H., Jr.

Report on the talc industry of St. Lawrence county [New York]. (15th Ann. Rept. of New York, pp, 661-671, 1897.)

Tower, G. W., Jr. (Emmons, F. H., and)

Economic geology of the Butte special district. (U. S. Geol. Survey, Geologic Atlas of the U. S., folio 38, Butte special folio, 6 pp., 3 maps, 1897.)

Turner, H. W.

Notes on some igneous, metamorphic, and sedimentary rocks of the coast ranges of California. (Jour. Geol., vol. 6, pp, 483-499, pl. 13, July-Aug. 1898.)

Udden, J. A.

Some preglacial soils. (Interglacial deposits in Iowa: A symposium presented at the Iowa Academy of Sciences, Des Moines, Iowa, Dec. 28, 1897; pp. 39-41. Reprinted from Proc. Iowa Acad. Sci., vol. 5, 1898.)

Udden, J. A.

The mechanical composition of wind deposits. (Augustana Library publications, No. 1, pp. 1-69, Rock Island, Ill., 1898.)

Upham, Warren.

Raised shorelines at Trondhjem. (Am. Geol., vol. 22, pp. 149-154., Sept. 1898.)

Weed, W. H.

Description of the Butte special district. (U. S. Geol. Survey, Geologic Atlas of the U. S., folio 38, Butte special folio, 3 pp., 3 maps, 1897.)

Whiteaves, J. F.

On some fossil Cephalopoda in the museum of the Geological Survey of Canada, with the descriptions of eight species that appear to be new. (Ottawa Naturalist, vol. 12, pp. 116-127, Sept. 1898.)

Whitfield, R. P.

Catalogue of the types and figured specimens in the palæontological collection of the geological department, American Museum of Natural History. (Bull. Am. Mus. Nat. Hist., vol. 11, pt. 1, pp. i-viii, 1-72, July 22, 1898.)

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CORRESPONDENCE.

ON THE OCCURRENCE OF CUBANITE AT BUTTE, MONTANA. Examination of a brass-yellow mineral that is now being mined for copper ore on the Speculator and Modoc claims near Butte, Montana, has led to the conclusion that the mineral is massive cubanite.

Cubanite is a copper and iron sulphide having the composition of $Cu\ Fe_2\ S_4$. Its theoretical composition is copper 20.87, iron 36.93, and sulphur 42.24 per cent. Two analyses of this ore made by Mr. S. J. Gormly, chemist for the Anaconda Copper Mining Company, at the request of the writer, gave the following results: copper, 25.35, 25.04, iron 34.90, 34,26, sulphur 39.05, 39,90, silica, 0.77, silver, 0.96 oz., and a trace of gold. The latter figure in each case is the more accurate. Other analyses not so reliable, reported to the writer showed 19.8 and 23.6 per cent of copper respectively. The specific gravity is 4.26.

In this analysis the copper percentage is high, being increased at the expense of the sulphur and iron. This is probably due to the presence of about 13 per cent. of bornite as a mechanical mixture, indications of the presence of that mineral having been noticed in the bright and variegated coloring of cleavage faces and joints.

The uniformity of color, differing from pyrite and chalcopyrite, in large masses more or less mixed with vein quartz, and the closeness with which the composition approximates both the analyses given by Dana, and the theoretical composition, lead to the presumption that the mineral is of this species though no crystalline forms have as yet been perfectly identified.

Its occurrence is in a vein which lies just north of a quartz porphyry dike, and parallel with it. It comes from the depth of about 200 feet.

So far as the writer is aware this is the first cubanite locally reported in the United States. HORACE V. WINCHELL.

Butte, Mont. Aug. 9, 1898.

DRIFT FORMATIONS OF LONG ISLAND.—I have referred so often to the drift formations of Long Island in the American Geologist that I feel somewhat reluctant to call the attention of its readers again to the same subject. Some remarks, however, made by Prof. Salisbury in the Journal of Geology on certain criteria of stratified drift deposits, which have only recently come under my notice, seem worthy of further remark. He says truly: "It is evident that the stratified drift may alternate with unstratified many times in a formation of drift deposits during a single ice epoch." I had some photographs taken to illustrate this very point along the terminal moraine in the city of Brooklyn. On the corner of St. Marks and Utica avenues where the altitude is about 160 feet above the level of the sea the complexity of the drift is very marked. Facing St. Marks, north side of the ridge, the stratification was exceedingly complex in character, the layers showing very much contortion, while just around the corner on Utica avenue facing west very little modification was visible.

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Below the so-called englacial till there was a coarse layer of partially stratified material and along the edges of the excavated section there were some signs of modification. On the northwest corner of the same avenue below the surface till, the whole mass seemed to be composed of stratified sand and gravel.

The moraine is very much broken along this section, as during the glacial floods there were many currents that flowed southward from the Wallabout depression and other basins on the north side of the island. The gaps in the ridge known as the "clove road," "Hunter's fly," and the historic "Jamaica pass" are all in this vicinity.

The point I desire to make, however, is this: The terminal moraine, which is supposed to mark the southern limit of the great continental ice-sheet, is more complex in character than the southern series of hills sometimes spoken of as "moraines of recession." This would hardly bear out Prof. Salisbury's suggestion that, "The exposed portions of the formation made by the ice-sheet which reached the greatest extension (the Kansan) should possess less complex contortion of stratified drift than the drift of the regions farther north which was affected by two or more ice-sheets."

It is true that the secondary moraine on Long Island shows a greater amount of stratification, but as stated, it is less complex in character than the southern moraine known as the backbone of Long Island. The reason for this, I have tried to explain in my "Ups and Downs of Long Island."* The glacial or subglacial rivers seem to have been more united and powerful on the north side of the island, for on leaving the bay depressions the streams became divided and ramified in such a way as to produce the diversity of drift along the line of the terminal which has generally been referred to as unmodified drift. While it is true that the southern ridge shows less signs of stratification than the northern series of morainic hills, it is nevertheless a fact, that the former contains a more complex modification. This modification takes place only along the old lines of drainage which are generally marked by a profusion of kettle holes, and marginal kames, as the late Prof. Carvill Lewis called them.

Prof. Salisbury in his remarks already referred to, says: "It is to be borne in mind, that the ice in many places doubtless destroyed all the stratified drift deposits in advance of the territory which it occupied later, and that in others, it may have left only patches of once extensive sheets. It also makes it clear that the relationship of the two sets of drift are on the whole less commonplace than they might have been, had all the deposits once made by the ice and its accompanying water, escaped decaption." The professor's theory is made to favor the duality of the ice age; but if the latter has to depend upon such arguments for support it has a very slender basis. I must say, however, that no writer has so well described the different criteria of the Long Island drift deposits, as I have observed them, although

*Am. Geologist, March, 1895, vol. XV, no. 3.

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Prof. Salisbury has doubtless studied them in a more distant field; and it has been very encouraging to the present writer as a layman to find his views so often confirmed by more learned authorities. It is only by comparing views and observations made in widely separated sections of the country, that correct solutions of the many perplexing problems can be arrived at.

I write in no captious spirit. My only desire is to aid in reaching the truth and that the cause of science may be somewhat advanced.

Eastport, L. I., N. Y., August 10, 1898. JOHN BRYSON.

BISON LATIFRONS AND BOS ARIZONICA. In my recent paper upon the remains of a Species of Bos in the Quaternary of Arizona reference should have been made to the important monograph by Dr. Allen upon the living and extinct American Bisons.* The reference is especially important inasmuch as Dr. Allen describes two large and perfect horn-cores from Adams county, Ohio, presented by Dr. O. D. Norton to the museum of the Nat. Hist. Soc. of Cincinnati, which cores, in size, shape and general proportions closely resemble the cores from Arizona. Excellent figures are given from a photograph about one-fifth size. The following are the dimensions, or measurements, of these cores :

Measurements of the Adams Co. Ohio Horn Cores.

Length of the Upper or concave side.....	32 inches or 813 mm.
Length of the lower or convex side.....	34 inches or 853 mm.
Circumference at the base.....	20 inches or 510 mm.
Circumference 10 inches from the base.....	16 inches or 407 mm.
Circumference 14 inches from the base.....	14½ inches or 368 mm.
Circumference 24 inches from the base.....	9½ inches or 240 mm.

The width of the skull between the horn cores is estimated to be 16 inches or 407 mm.

Allen observes that "the remains of the larger extinct bisons so far as yet known are not only few in number but come from not very widely separated localities, and that the great deposits of bones found at the Kentucky salt licks, especially that of Big Bone Lick, have yielded, thus far, no remains that have been identified as belonging to this gigantic representation of the ox tribe although containing the remains of Mastodon, Elephant, Megalonyx and Mylodon, together with those of the fossil horse, the great extinct musk-ox, the lesser extinct bison, the extinct peccary, the caribou and the moose."

The remains from Ohio, Nebraska and Arizona indicate a much wider distribution of the gigantic animal than was known at the time of publication of Allen's monograph. In the map indicating the geographical range of the bison the area does not extend as far as the Arizona line.

While Europeans generally have referred the American remains of the extinct bos and bison to Bison priscus of the old world it was the opinion of Dr. Allen. and it is apparently well sustained by the later discoveries, that the remains indicate an animal so immensely superior in

*American Bisons Living and Extinct, Memoirs, Mus. Comp. Zoology, Cambridge, IV. No. 10, 1876. An addendum containing a reference to this monograph reached the publishers too late to be incorporated in this article.

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size to the Bison priscus of the old world as to leave little reason for questioning its distinctness.

For notes on the Osteology of Bison antiquus, and a comparison of the remains of B. antiquus and B. latifrons, reference may also be made to a memoir by Alban Stewart*in which he discusses the wide geographical distribution of B. antiquus, showing that the animal had a range over the greater part of North America.

WM. P. BLAKE.

Tucson, Ariz. and Mill Rock,
New Haven, Ct.

GEOLOGY AND GEOGRAPHY AT THE AMERICAN ASSOCIATION MEETING.

The meeting of the American Association for the Advancement of Science, held in Boston, under the presidency of Prof. F. W. Putnam, on August 22d to the 27th of this year, the fiftieth anniversary since the formation of this Association, was one of the most interesting and successful in its history. The enrolled attendance was 903, representing thirty-five states, the District of Columbia, Canada, Brazil, Great Britain, France, New South Wales, and Japan. The number of new members elected was 273, bringing the membership up to about 1,900. The number of papers presented was 443, of which 55 were read in the sessions of Section E (Geology and Geography), as hereafter noted.

By the invitation of Section E, meetings of the Geological Society of America and the National Geographic Society were held with this Section, the former in three sessions on Tuesday forenoon, afternoon, and evening, August 23rd, and the latter on Thursday afternoon, the 25th. These sessions, and those of Section E, were held in the lecture room of the Boston Society of Natural History, excepting the final session on Friday forenoon, which was held in the geological lecture room of the Museum of Comparative Zoölogy, in Cambridge.

The address by the vice president of Section E, Prof. Herman L. Fairchild, of Rochester, N. Y., on "Glacial Geology in America," was presented on Monday afternoon. It is published in the September issue of this magazine.

Another address of much interest to geologists was given by Prof. A. S. Packard, of Providence, R. I., vice president of Section F (Zoology), entitled, "A Half-century of Evolution, with Special Reference to the Effects of Geological Changes on Animal Life," published in Science for August 26th and September 2d and 9th.

Excursions for geological observations were made in the vicinity of Boston, Salem, Braintree, etc., under the guidance of Profs. W. O. Crosby, G. H. Barton, and J. E. Wolff, and of J. H. Sears, A. W. Grabau, and others.

In the opening session of Section E with the Geological Society, on Tuesday forenoon, short memorial addresses on the life and work of the late Prof. James Hall were given by Profs. Emerson, Fairchild,

*Kan. Univ. Quar., Vol. VI, No. 3, July, 1897, Series A, p. 127.

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and Niles, and by Dr. Horace C. Hovey, noting Hall's earnestness in boyhood and youth to acquire knowledge of geology and allied sciences, walking twenty miles from his home in Hingham, Mass., to attend lectures by Benjamin Silliman before the Boston Society of Natural History, his distinguished service of more than sixty years on the Geological Survey of New York, and his recent illness and death August 7th.

The papers presented before the Geological Society of America, with brief notes of their scope, mostly as stated in the Society's preliminary announcement, were as follows:

1. Some Features of the Drift on Staten Island, N. Y. By ARTHUR HOLLICK, Columbia University, New York City. The terminal moraine crosses Staten Island from Fort Wadsworth at the Narrows to Tottenville, opposite Perth Amboy, N. J. Its front rests partly upon the serpentine ridge and partly upon the plain region to the south. In the former locality it consists of true morainal material of the northern drift. In the latter it comprises a ridge or core of Cretaceous and Tertiary clays, sands and gravels shoved forward and upward from their original position on the island, and on top of these disturbed beds are the morainal till and gravel. At two localities there are well defined indications of extra-morainic drift, south of the terminal moraine. The direction of glacial movement is indicated by the striæ on rock outcrops to be about S. 17° E. The most abundantly represented bowlders are those derived from the Triassic of New Jersey, although nearly all the outcrops between Staten Island and the Adirondacks have contributed. A list of about 120 Paleozoic fossils obtained from the transported bowlders was appended to this paper with another list of about 35 Cretaceous and Tertiary species, mostly fossil plants, derived from the disturbed Staten Island strata.

2. Loess Deposits of Montana. By Prof. N. S. SHALER, Cambridge, Mass. (Read by title.)

3. Glacial Waters in the Finger Lake Region of New York. By Prof. H. L. FAIRCHILD, Rochester, N. Y. This paper noted the stages of glacial retreat and consequent changes of drainage by which the glacial lake Newberry, outflowing southward to the Susquehanna, was succeeded by lake Warren, about 100 feet lower; and this, when the ice was further melted back, by lake Iroquois. For the most definite stage between lakes Warren and Iroquois, represented by a large beach at Geneva, N. Y., and by an old channel of eastward outflow south of Syracuse, the name lake Dana is proposed.

4. The Stratification of Glaciers. By Prof. HARRY F. REID, Baltimore, Md. Lantern views of the glaciers of Switzerland and Alaska were displayed, attention being directed to the author's observations of the persistency of the original stratification occasioned by the snowfall of successive years on the névé. This structure was distinguished from the transverse blue banding, analogous with cleavage, which is occasioned by pressure of the moving ice, being especially developed in constricted or very steep parts of the glaciers.

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5. Evidences of Epeirogenic Movements Causing and Terminating the Ice Age. By WARREN UPHAM, St. Paul, Minn. The vertical amount of the preglacial elevation of North America, during late Tertiary and early Quaternary time, is shown to have ranged from 3,000 to 5,000 feet, according to the soundings of fjords and submerged valleys on our Atlantic, Pacific and Arctic coasts, the deepest of these valleys, exceeding 5,200 feet, near Monterey, California, having been described by Davidson a year ago. Similarly it is also known that a general uplift of western Europe and western Africa took place at or near the same time, of varying amount from a minimum of probably about 1,500 feet in the British Isles to maxima of about 4,000 feet in Scandinavia, nearly 9,000 feet in the country adjoining the southeast part of the bay of Biscay, and more than 6,000 feet at the mouth of the Congo. These great uplifts are thought to have given the cold and snowy climate under which the ice-sheets were amassed. But the lands were afterward depressed, in the closing or Champlain epoch of the Glacial period, to levels mostly somewhat below their present hights, whereby a temperate climate, with warm and even hot summers, was restored on the borders of the ice-sheets, melting them gradually from the periphery inward. Steep frontal gradients and vigorous glacial currents were thus produced, heaping much of the drift in prominent recessional moraines.

6. Clayey Bands of the Glacial Delta of the Cuyahoga River at Cleveland, O., Compared with those of the Implement-bearing Deposits of the Glacial Delta at Trenton, N. J. By Prof. G. FREDERICK WRIGHT, Oberlin, Ohio. A year ago Profs. Wright, Hollick, Mercer, and Libbey, made excavations at Trenton in the field where Mr. Ernest Volk has been working under the direction of Prof. Putnam. As a result of their work, they found several implements from three to four feet below the surface, and beneath certain red clayey bands which they supposed to be a part of the original delta deposited at Trenton during the close of the Glacial period. In the meetings of the American and British Associations, however, at Detroit and Toronto last year, vigorous efforts were made by others to prove that these clayey bands do not belong to the original water deposition, but may have been wind-blown surfaces or lines of oxidation in the sand. During the past year Prof. Wright has made numerous observations upon excavations in a similar delta of Glacial age at Cleveland, where he finds a succession of reddish clayey bands in the sand precisely similar to those at Trenton; and at Cleveland they merge into cross-bedded sand and gravel on the same level, showing unequivocally that the whole is a water deposit, and that it has not been disturbed since the original deposition. This strongly confirms the inferences drawn a year ago concerning the age and undisturbed character of the deposits at Trenton from which Mr. Volk has derived so many implements for Prof. Putnam, indicating that men were present, making, using, and losing these implements at the time of departure of the ice-sheet.

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7. The Middle Coal Measures of the Western Interior Coal Field. By H. FOSTER BAIN and A. T. LEONARD, Des Moines, Iowa. The lower coal measures of the western interior coal field are marked by non-persistence of strata. The upper measures are more regular. Between the two is a series partaking of some of the characteristics of each. This series includes the Raccoon River beds, the Appanoose formation and equivalents in Iowa; the Henrietta in Missouri; and the Oswego and Pawnee limestones of Kansas. No fitting general term for the whole has yet been proposed. The old term, middle coal measures, included the beds here referred to and the higher beds now quite generally known as the Pleasanton shales.

8. The Principal Missourian Section. By CHARLES R. KEYES, Des Moines, Iowa. The previous classifications of the Carboniferous formations of the region west of the Mississippi river were briefly outlined. The results of the recent work along the Missouri river were summarized, and the inferences to be drawn were given. The Missourian series, as one of the four principal subdivisions of the Carboniferous of the continental interior, was described. Eleven well defined formations or stages are shown to have a wide distribution, the formations in five states being correlated.

9. Tourmaline and Tourmaline Schists from Belcher Hill, Jefferson County, Colorado. By HORACE B. PATTON, Golden, Colo. Black tourmaline, often in fine large crystals, occurs very abundantly in pegmatite veins that cut the crystalline schists of the foot-hills of Jefferson county, west of Denver, Colorado. On the Belcher Hill road near Golden the tourmaline occurs (a) in separate crystals; (b) in black masses (schorl) in quartz veins; (c) the same in pegmatite veins; and (d) in finely disseminated needles replacing biotite and even feldspar and quartz in biotite schists and gneisses at contact with veins of pegmatite and quartz. The beautiful banding and cross-banding produced by this replacement is unusual. The paper was illustrated by specimens and photographs.

10. Magmatic Differentiation in the Rocks of the Copper-bearing Series. By ALFRED C. LANE, Houghton, Mich. In many of the effusive sheets a difference may be noted between the top and the bottom. At the top the feldspar is oligoclase, at the bottom labradorite. At the top olivine is more conspicuous, at the bottom augite. The oligoclase and olivine were evidently formed before the lava from which the sheet was formed came to rest, at least in part. The augite and labradorite were probably formed later. It is possible that the early formed oligoclase rose to the top, and that the sodiferous magma there formed had not so corrosive action on the olivine as the calcareous magma left below, which latter may have corroded the olivine and out of it formed augite. Comparing different flows, we find the same kind of relations that exist between the top and bottom of the same flow. This suggests that similar differentiation went on before eruption.

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11. The Volume Relations of Original and Secondary Minerals in Rocks. By Prof. CHARLES R. VAN HISE, Madison, Wis. This paper discusses the volume relations of secondary minerals as compared with original minerals, and considers this volume change in reference to the depth at which the alteration occurs.

12. Note on a Method of Stream Capture. By ALFRED C. LANE, Houghton, Mich. When the divide between two streams is porous, and the valley of the one is much deeper than the other, springs may arise on the side of this deeper valley, which drain the water from the higher valley and thus diminish the erosive capacity of the stream therein, until the higher valley has a stream only in times of rain, and is soon eaten into by lateral tributaries of the deeper stream. Various illustrations of this action were given; and it was noted that during the Glacial period the streams draining the ice-front were especially liable to capture, because they occupied channels heavily filled with porous gravel and sand.

13. The Development of the Ohio River. By Prof. WILLIAM G. TIGHT, Granville, Ohio. A brief review of the literature shows that the generally accepted view has been that the Ohio river is a very ancient stream; but recently the work of several geologists in New York and Pennsylvania indicates the Pleistocene origin of the Ohio above New Martinsville. In papers already published by the author the existence of a very ancient erosion basin extending in general from east to west through the central part of Ohio and Indiana is established by the restoration of many tributary drainage lines and by deep wells. Further evidence is presented in this paper to show that the Ohio in its present location has been established through the appropriation of sections of numerous northwardly and northwestwardly flowing streams by the cutting of the ancient cols and the broadening and deepening of the valleys. The explanation for these changes is found in the position and action of the ice-sheet in the various sections, thus determining also the age of this part of the Ohio valley to be Glacial or Postglacial. The lines of discharge of the glacial waters determined the present lines of southwardly flowing tributaries of the Ohio. The preglacial drainage lines of the Ohio basin were intimately related to many features in the development of the Alleghany plateau and the great Appalachian valley and to the erosion basins in which the great lakes are found.

The theory is proposed that the development of the Ohio river almost entirely beyond the greatest extent of the ice-sheet, and the development of the Missouri almost entirely within the limits of the ice, were due to the different angles which these streams made with the advancing ice-front, and to their different gradients. In the Ohio basin the water was forced over distant cols; but in the Missouri basin it was drained southeastward along the ice-front, thus wearing back the ice at the time of final recession before the establishment of the channel by erosion.

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14. Classification of Coastal Forms. By F. P. GULLIVER, Southboro, Mass. A scheme is proposed in this paper for the classification of the various forms of the coast according to their stage of development. Two markedly different classes of initial forms are recognized, those following elevation of the land and those following depression. Each class is seen to have characteristic forms at various stages of its development, and the writer urges others to think of all the forms on the coast or along the shore as in a certain stage of their life-history. This will further suggest the form from which any given example has come and toward what form it tends to develop.

15. Dissection of the Ural Mountains. By F. P. GULLIVER. The Urals are seen to be pretty thoroughly planed, so that the summits of the many ridges rise to nearly the same elevation, except a few commanding peaks which are found to consist of quartzyte or other rock more resistant than the surrounding beds. The summit-level plane descends gradually to the west until it merges into the upland levels of the great plain of Russia, while on the east in several places there is a rather steep fall-off to the Siberian plain, though in other places the plane of the summits merges into that of the great Tertiary deposits of northwestern Asia.

Planation in general was then taken up, and distinctions were sought between planed surfaces formed in three ways: first, those formed by rivers wearing down the land to baselevel; second, those produced by the attack of the sea upon a stationary land-mass; and third, abrasion surfaces resulting from sea attack on a slowly sinking land-mass.

The stages of dissection in various parts of the Ural mountains, and the grade-plains of different streams, were compared; the result of such comparison being that there seem to be three epicycles or divisions of the present cycle of erosion. (Illustrated by lantern slides.)

16. Note on Monadnock. By F. P. GULLIVER. The relation of Monadnock to the New England upland was considered, and the valleys in the vicinity of this mountain were described. The elevations of two former stream grades have recently been determined in this region.

17. Spacing of Rivers with Reference to the Hypothesis of Base-leveling. By Prof. N. S. SHALER, Cambridge, Mass. (Read by title.)

18. The Continental Divide in Nicaragua. By C. WILLARD HAYES, Washington, D. C. The comparatively short streams, with steep gradients, descending to the Pacific, have in numerous instances increased their drainage basins by capture of the headwaters of streams flowing eastward to lake Nicaragua and the Caribbean sea. In this way the water divide on the surveyed line for the Nicaragua canal has been removed a considerable distance eastward, being

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now at a much lower altitude than the original mountainous watershed.

In the session of the National Geographic Society with Section E, the following papers were presented:

1. The Venezuela-British-Guiana Boundary Dispute. By Dr. MARCUS BAKER, Washington, D. C.

2. Considerations Governing Recent Movements of Population. By JOHN HYDE, Washington, D. C.

3. Some New Lines of Work in Government Forestry. By GIFFORD PINCHOT, Washington, D. C.

4. The Development of the United States. By W J McGEE, Washington, D. C.

5. Atlantic Estuarine Tides. By M. S. W. JEFFERSON.

6. The Forestry Conditions of Washington State. By HENRY GANNETT, Washington, D. C.

7. The Five Civilized Tribes and the Topographic Survey of Indian Territory. By CHARLES H. FITCH, Washington, D. C.

8. Bitter Root Forest Reserve. By RICHARD U. GOODE, Washington, D. C.

It is expected that several of these papers will be published in the National Geographic Magazine.

The papers of Section E were as follows:

1. Outline Map of the Geology of Southern New England. By Prof. B. K. EMERSON, Amherst, Mass. This paper, with maps, gave a summary of the areal geology of Massachusetts, Rhode Island, Connecticut, and parts of New Hampshire, Vermont and New York.

2. Basins in Glacial Lake Deltas. By Prof. H. L. FAIRCHILD, Rochester, N. Y. During the glacial recession, the impounded high waters of the Canandaigua valley, in central New York, at one time escaped across the eastern border of the basin into the Flint creek valley, which was also occupied by a glacial lake at a lower level. The river thus formed cut a channel in drift and rock, and deposited the debris, as a delta, at its mouth in the lower lake. The delta now forms a conspicuous plateau of gravel 125 above the village of Potter. In this plateau is an irregular depression which reaches to the very base of the delta deposit, and occupies perhaps one-fourth of the area of the plateau. The only satisfactory explanation of its origin is that an isolated block of ice was left here by the receding ice-front, and that the delta material was piled around it, the subsequent melting of the ice block producing the cavity. Elsewhere shallow basins occurring in deltas are in many cases attributable to deficient filling by capricious currents and wave action; but such bowls cannot be confounded with the Potter kettle-hole, which was illustrated by a map and photographs.

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3. An Exhibition of the Rare Gems and Minerals of Mt. Mica. By Dr. A. C. HAMLIN, Bangor, Maine. (Read by title.)

4. The Hudson River Lobe of the Laurentide Ice-sheet. By Prof. C. H HITCHCOCK, Hanover, N. H. The drift and striæ of Quebec, New England, and New York, prove the existence of a glacial lobe following the Champlain-Hudson valley. The movement was to the southeast over the summits of the White and Green mountains and to the southwest over the Adirondacks, but due south along the medial valley. Last October the author climbed Orford mountain, which rises northwest of lake Memphremagog to an altitude of about 5,000 feet above the sea, and found it glaciated from bottom to top, wholly in a southeasterly course. All over the mountain were found boulders of Laurentian gneiss, which (according to their determination by Prof. Frank D. Adams of Montreal) must have come from the north side of the St. Lawrence river. It had before been shown that the highest mountains of New Hampshire and Vermont were glaciated from the northwest, but doubt had been lately expressed about Orford mountain. These observations prove that the Laurentide ice-sheet overrode all these mountains, flowing from the region north of Montreal and Quebec southward and southeastward to the sea border.

5. The Age of the Amboy Clay Series as indicated by its Flora. By ARTHUR HOLLICK, Columbia University, New York City. Investigations in the paleobotany of the Amboy Clay series of New Jersey and the equivalents on Staten Island, Long Island, Block Island, and Martha's Vineyard, conducted during the past twenty years by the late Dr. J. S. Newberry, Dr. Lester F. Ward, Mr. David White, the writer, and others, have shown that the formation which includes them is very closely related to the Atane and Patoot beds of Greenland, the Dakota group of the west, the Albirupean series of the south, and the Cenomanian of Europe, so that there was no hesitation in declaring them all to be Middle Cretaceous in age. This conclusion seemed to be quite generally accepted, and was apparently not questioned until about two years ago, when an announcement was made, with some show of authority, that the series is probably Jurassic in age. In regard to the correlation of the several formations previously mentioned there can be no question. The large amount of paleobotanical material available for comparison has given opportunity for the identification of so many species common to them all that this conclusion is not only justifiable but inevitable; and the only question is whether this correlation also demonstrates that the several formations are Middle Cretaceous in age. If any one of them is, then they all are; if any one is not, then the others are not.

In paleobotany, as in paleozoology, the broad general facts are recognized that the biological sequence is coincident with the geological sequence, and that the further back in geologic time the simpler and lower in the scale of life were the organisms. Hence if we divide

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our fossil flora into three great classes of cryptophytes, gymnosperms, and angiosperms, the sequence of their appearance and periods of maximum development would be in the same order. The percentages of these classes in any floras should therefore be a fair indication of the relative ages of the floras. A typical Jurassic flora, such as that of Siberia, contains, roughly, the following percentages: cryptophytes, 22; gymnosperms, 74; and angiosperms (?), 4. The older Potomac flora, which is regarded as lower Cretaceous, contains the same classes in the percentage of 39, 39, and 22; the newer Potomac, regarded as Middle Cretaceous, 8, 13, and 79; the Amboy clays, 6, 13, and 81; the Dakota group, 1, 5, and 94. Similar examples of percentages were also calculated for other floras regarded as Cretaceous in age. The main fact, which is at once seen, is the manner in which the percentages of the gymnosperms and angiosperms are reversed. Few angiosperms, and only those of a doubtful character, have been found in any formation recognized as Jurassic; so that when it was ascertained that in the Amboy Clay flora and its equivalents the angiosperms represent from 70 to 90 per cent. of the entire flora, there was little hesitation in considering it as well advanced in the Cretaceous period. There would be nothing inconsistent in regarding the lowest of the older Potomac strata as Jurassic, but even there it would require definite paleontologic evidence, while in regard to the Amboy Clay series it is safe to say that a Jurassic fauna will never be found in connection with its flora.

In face of the direct evidence of the fossil flora, therefore, it would seem a very hazardous undertaking, without ample evidence in rebuttal, to draw the line of separation between the Jurassic and Cretaceous so that in the west the base of the Cretaceous would be represented by the Dakota group and in the east by the clay marls of the Matawan formation. (The paper was illustrated by tables of percentages and charts.)

6. Some Feldspars in Serpentine, Southeastern Pennsylvania. By Prof. T. C. HOPKINS, State College, Pa. Feldspar occurs in this district as dikes or veinlike masses in serpentine, sometimes attaining a thickness or width of 20 to 25 feet. The most extensive area is in Chester county, extending also into Lancaster county; but there is another area in central Chester county, near the corundum mines. The feldspar is snow-white to pink in color, and seems to be wholly orthoclase. Some of the dikes have been exploited to a depth of 60 feet.

7. The Region of the Causses in Southern France. By Rev. HORACE C. HOVEY, Newburyport, Mass. Lofty tablelands in the departments of Lot and Lozére, along the western declivity of the Cevennes mountains, are known as the Region of the Causses. The term "Causse" is derived from the Latin word calx, meaning limestone. Some of the finest roads in Europe run along the plateaus, and occasionally descend into the valleys. But the author's explora-

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tion, here noted, led by E. A. Martel, of Paris, left all beaten paths at the village of St. Enimie, and in canoes followed the winding gorges of the Tarn for 46 miles, and then by mules, or in carriages, examined the gorges of the Jonté and Durbais. The Causses vary in hight from 1,000 to 5,000 feet above the sea, and these gorges are cut through them somewhat as the grand canon of the Colorado cuts through the plateaus of Arizona. The cliffs of the river Tarn are often from 1,000 to 2,000 feet high, and occasionally still higher, and are brilliantly colored.

The caverns of the region are as remarkable as any in Europe. There are hundreds of them and of all sizes. Among the large caverns explored by this party may be mentioned those of the Baumes Chaudes. These are three in number. From one of them the late Dr. Pruniéres exhumed 300 prehistoric skeletons, and in another are nine vertical pits from 40 to 127 feet deep. Another cave destined to become famous is that of Darjelan, with twenty halls from 65 to 600 feet long, the lowest of them being 420 feet deep. The author's party discovered and explored the Aven Armand, down whose chasm Louis Armand was the first to go. This vertical pit is 240 feet deep, beyond which is another 300 feet deep, the total vertical depth being 600 feet by actual measurement. The descent was made by a series of rope ladders, and was not without its dangers. The stalactitic decoration of these caves is remarkably fine.

The term "aven" is applied to what we call a "sink-hole," excepting that the avens seem to pass more abruptly into pits or chasms. They pierce the Causses from the summit to the drainage level, and are death-traps for animals, whose remains were found below in various stages of decomposition, and whose bones lie imbedded in the dripstone. The theory is that every aven has a passageway to the rivers of the region. That this is often so is proved by the great springs at the base of the cliffs of the Tarn; but in some cases the passageways trend away from the streams instead of toward them, and often they are dry, showing that the drainage must have been at some remotely ancient period.

Should it be asked why the wonderful region of the Causses has so long escaped exploration amid a country of high antiquity, the answer is that these lofty plateaus are barren solitudes, except for the chalets of wandering shepherds. The gorges and avens have been objects of dread instead of places attracting visitors. The superstitions of the peasants have also operated to make them shun what a few tourists now delight to explore. Under the stimulus of the Société de Spéléologie, the region is being opened to the public, and it is destined to be resorted to by thousands of tourists when its interesting features become more widely known.

8. The Washington Limestone in Vermont. By C. H. Richardson. Hanover, N. H. This name is proposed by the author for the more calcareous member of the Calciferous mica schist of Prof.

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C. H. Hitchcock. It is for the most part a very dark silicious rock, the color of which is due to finely disseminated carbon. This formation, varying from 2,000 to 5,800 feet in thickness, extends from south to north through Vermont; but its most important development, economically, is in the townships of Washington and Topsham, Orange county, where, within the past five years, numerous valuable marble quarries have been opened in it. The chemical composition of specimens of the marble from a deep test pit at one of the quarries is very remarkable, no less than eighteen elements having been detected in its analysis.

9. Fluctuations of North American Glaciation shown by Interglacial Soils and Fossiliferous Deposits. By WARREN UPHAM, St. Paul, Minn. From a comparison of our continental drift deposits with the present retreatal conditions of the piedmont Malaspina glacier in Alaska, it is concluded that the flora and fauna adjacent to the retiring ice-sheet were nearly like those of the same latitudes to-day, and that fluctuations of the ice-border to the extent of a few miles, a few score, or a few hundred miles, at different stages of the ice age, due to moderate secular climatic changes, more acceptably account for our interglacial beds, former surface soils and leached subsoils, than a general departure and renewal of the ice-sheet.

No more surprise need be occasioned by the occurrence of remains of warm temperate floras and faunas in these beds than we must feel in seeing tropical and temperate plants and animals at the foot of the Himalayas and the Alps. These extensive mountain ranges, frigid and largely snow-covered, doubtless exert as much influence on the climate of the contiguous valleys and lowlands as could be due to the waning ice-sheets of North America and Europe, when the Early Glacial high continental altitude was succeeded by the Late Glacial or Champlain depression of these great areas somewhat below their present level. The ice-sheet of each of these continents, in its time of retreat, being wasted by a warm climate at its edge, probably rose to an altitude of 5,000 feet above the land within 100 or 200 miles back from the ice border, which therefore might considerably readvance during any series of exceptionally cool years, with plentiful snowfall.

10. Time of Erosion of the Upper Mississippi, Minnesota and St. Croix Valleys. By WARREN UPHAM. Until the Ozarkian epoch of great elevation of the northern part of this continent, inaugurating the Quaternary era, the upper part of the present Mississippi basin, above the vicinity of Dubuque, appears to have been drained northerly, according to recent studies by Hershey (Am. Geologist, XX, 246-268, Oct., 1897). After the Cretaceous marine submergence of the state of Minnesota, its chief river system probably flowed through the Red river valley to Hudson bay during the Tertiary era, being reversed to take nearly the course of the Minnesota and Mississippi rivers at the end of that era. The St. Croix river is thought by the author to have obtained its passage through the rock gorge of the Dalles at

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Taylor's Falls, Minn., so late as the Buchanan interglacial epoch, preceding the Illinoian and Iowan glacial readvance; and the channel of the Mississippi from Minneapolis to Fort Snelling, eroded during the Postglacial period, has afforded to Prof. N. H. Winchell his well known estimate of that period as between 7,000 and 10,000 years.

11. Supposed "Corduroy Road" of Late Glacial Age, at Amboy, Ohio. By Prof. G. FREDERICK WRIGHT, Oberlin, Ohio. This paper detailed the discovery of a series of logs lying side by side as in a corduroy road, and extending for a distance of 200 feet or more, which were covered by 30 feet of gravel in which were found the tooth and tusk of a mammoth, the tusk being ten feet long, twenty-two inches in circumference at the base, and weighing 155 pounds. The resemblance to a corduroy road was indeed very striking; but the appearance of the logs showed that they were driftwood, and had been buried by the accumulation of the gravel that took place along the old shore of lake Erie, when, during the closing centuries of the Glacial period, the water was held up to a level 150 feet higher than now. The logs and base of the deposit are 140 feet above the lake, and about four miles back from it, on the banks of Conneaut creek, in the extreme northeastern corner of Ohio. The gravel was evidently brought down from the higher lands to the south, near the sources of the creek, and was deposited with the mammoth remains in a delta at the edge of this old glacial lake. In connection with this investigation, it was ascertained that similar deltas of gravel characterize the margin of the old lake where other streams from the south met it at various places between this point and Cleveland. Altogether these observations give a very vivid picture of the rapidity with which coniferous forests proceeded to cover northern Ohio as the ice melted back, and of the promptness with which the immense animals of the time reöccupied the territory. Important inferences are also derived, showing that the period of time during which the water remained at the high levels of the old ice-dammed lakes was short.

12. Changes in the Drainage System in the Vicinity of Lake Ontario during the Glacial Period. By Dr. M. A. VEEDER, Lyons, N. Y. The paper noted sections of wells in buried river channels south of lake Ontario, from the Niagara river eastward to the Mohawk valley.

13. Recent Severe Seismic Movements in Nicaragua. By JOHN CRAWFORD, Managua, Nicaragua. Description of a series of earthquakes in western Nicaragua, April 29th to May 12th of this year, as reported by the author in this magazine for July (vol. xxii, pp. 56-58.).

14. Another Episode in the History of Niagara River. By J. W. SPENCER, Washington, D. C. This paper is a sequel to one read before the American Association four years ago on the duration of Niagara falls. It announces the discovery that while the falls were receding from Foster's flats to the locality of the railway bridges, the fall of the river reached its maximum amount of 420 feet by the

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retreat of the Ontario waters toward the north; and that, during the later part of this recession of the falls, past the Whirlpool rapids, the return to the present amount of 326 feet descent was interrupted by the rising of the level of the lake in the gorge to a hight of 75 feet above its present level, thus reducing the actual fall of the river to 250 feet. The evidence of this is preserved in the remains of a terrace deposit opposite the foot of Foster's flats and a corresponding terrace just outside the mouth of the gorge; and these terraces, with other parts of the shoreline in the Ontario basin which marks the rise of the water so as to flood the Niagara gorge, are here named the Niagara strand. The rising of the waters was occasioned by the lifting of the barrier at the outlet of lake Ontario to an elevation 100 feet higher than now. By the subsequent erosion of this barrier, which was partly composed of drift, the actual fall of the Niagara waters has been increased to its present figure. The reduction of the descent of the river is found to be sufficient to account for the shallowness of the channel at the Whirlpool rapids. The narrowness of this section is explained by the fact that the youthful Niagara took possession of a small preglacial valley there, giving greater depth to the river. It is further probable that the volume of the river was less at that time, since it is supposed that a portion of the outflow of the great lakes passed to the Mississippi.

15. The Age of Niagara Falls as Indicated by the Erosion at the Mouth of the Gorge. By Prof. G. FREDERICK WRIGHT, Oberlin, Ohio. The late Dr. James Hall early noted the significant fact that "the outlet of the chasm below Niagara falls is scarcely wider than elsewhere along its course." Clearly this is important evidence of the late date of its origin, and it has been used by the author and others in support of the short estimates which have been made concerning the length of time separating us from the Glacial period. A close examination made by the author this summer greatly strengthens the force of the argument, since he found that the disintegrating forces tending to enlarge the outlet and to give it a V-shape are more rapid than has been supposed. The depth of the gorge at the outlet, from the top of the Niagara limestone to the river, is 340 feet. The thickness of that formation of limestone at the surface is here, however, only about 40 feet; while the soft Niagara shales underlying it are from 60 to 75 feet thick. Below there is a stratum of Clinton limestone 30 feet in thickness, and below that a shaly deposit of 70 feet. The Niagara shales at this point have never been covered by talus; so that they have always been accessible to disintegration by atmospheric agencies.

Somewhat over forty years ago, a railroad was built along the face of the eastern side of the gorge, affording an opportunity to observe the rate of disintegration. All along where a perpendicular exposure was made, the shale has crumbled away to an extent of several feet, and in some places to that of twenty feet. A conservative

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estimate of the rate of disintegration for the 70 feet of Niagara shales supporting the Niagara limestone would be one inch a year, with a probable rate of two inches a year. But at the lowest estimate no more than 12,000 years would be required for the enlargement of the upper part of the mouth of the gorge 1,000 feet on each side, which is very largely in excess of the actual amount of enlargement. Some of the recent estimates, therefore, which would make the gorge from 30,000 to 40,000 years old, are evidently extravagant, and must incorporate some error in their premises. The age of the gorge cannot be much more than 10,000 years, and probably considerably less.

16. A Recently Discovered Cave of Celestite Crystals at Put-in-Bay, Ohio. By Prof. G. FREDERICK WRIGHT. The principal locality in America from which museums have been supplied with specimens of celestite (sulphate of strontium) is Strontian island, two or three miles from Put-in-Bay island, in the western end of lake Erie. Just as this supply was becoming exhausted, a remarkable fissure was discovered last winter on Put-in-Bay island which is completely surrounded with very large crystals of this beautiful mineral. The fissure was penetrated in digging a well seventeen feet below the surface, and is large enough to permit the entrance of ten or twelve people at a time. It is not an ordinary cavern, but apparently is the interior of an immense "geode" lined with celestite crystals. The geological formation in which it occurs in the Waterlime of the Lower Helderberg. Large deposits of gypsum occur in the vicinity.

17. Geography and Resources of the Siberian Island of Sakhalin. By Prof. BENJAMIN HOWARD, London, England. Sakhalin has a length of about 670 miles and a breadth of from 20 to 150 miles. The features which the author observed during his visits to the island in 1890 and 1896, as described in this address, are (1) the absence of natural harbors and reliable anchorages around its entire 1,500 miles of coast, and the reasons for it; (2) the contrast which this island, having no volcanoes, exhibits as compared with the volcanic chain of the whole Japanese group and its continuation in the volcanoes of Kamtchatka; (3) the contradiction which Sakhalin, possessing an almost subarctic climate, affords to the popular belief that latitude is the dominant factor in the determination of climates; (4) its mineral resources, especially coal and iron; (5) the immensity and density of the fish shoals in the neighboring waters; (6) the absence of navigable rivers; (7) the persistence of unadulterated life and manners in the aboriginal Ainos there, as when described nearly three thousand years ago by the oldest Japanese historian; (8) the vast numbers of medusæ (jelly-fish) along the southern coast, and the marvelous phosphorescence of the sea as observed by the author; (9) the strategic value of the island to Russia; (10) the completeness of its adaptation to its present use as a penal stronghold; (11) the present development of its agricultural and mineral resources, and its prospective self-maintenance chiefly from its future fishing industries; and

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(12) the expediency of maintaining the spelling of the word Sakhalin, as here used.

18. Evidence of Recent Great Elevation of New England. By J. W. SPENCER, Washington, D. C. The paper was a description of the valley terraces in mountainous parts of New England, illustrated by sections showing that the declivities of the valleys are not by even slopes but by a succession of steps, the plains of which become terraces farther down the valley. These steps are regarded as gradation plains in the changes of the baselevel of erosion, and many of the corresponding terraces are hundreds of feet above the floors of the valleys. From these features it is inferred that the recent rise of the mountainous region can be approximately measured by the sum of the hights of the steps. Yet it is not inferred that the elevation need to have been from below the sea level; and consequently the gravels are not claimed to have been necessarily of marine origin.

19. The Oldest Paleozoic Fauna. By G. F. MATTHEW, St. John, N. B. This fauna is contained in a series of beds unconformably underlying the Cambrian system in eastern Canada and Newfoundland. The base of the Cambrian in the former country is marked by a barren sandstone, and in the latter by conglomerates. Erosion of the lower terrane continued up to and included the time of the Paradoxides fauna. The relation of these two terranes is compared to that of the Upper and Lower Silurian in New York or the Carboniferous and Subcarboniferous in eastern Canada. The fauna known consists of about twenty species. It contains no trilobites, either in eastern Canada or Newfoundland. Various forms of the family Hyolithidæ are the dominant types. Other gastropods allied to Capulus and Platyceras occur; also brachiopods; remains of echinoderms (cystids?); and corals allied to Archæocyathus and Dictyocyathus. The thin limestones which occur in the upper half of the terrane are supposed to have originated chiefly from foraminifera (Globigerina, etc.).

20. The Oldest Known Rock. By Prof. N. H. WINCHELL, Minneapolis, Minn. After allusion to the vague ideas formerly entertained of the rocks now included under the term Archean, and still surviving in some places, this paper, by a general diagram, presented the Archean as recently made out by the Geological Survey of Minnesota. With a brief description of the other members of the Archean in Minnesota, the author more particularly described the so-called greenstones of this state, which he considers the bottom of the Archean scale and the representative of the original crust of the earth formed from the molten mass by the earliest consolidation. The greenstones are divisible into two parts, one igneous and the other clastic, the latter succeeding the former with a confused and sometimes non-conformable superposition, somewhat as surface eruptive rocks might be superposed, in the presence of oceanic action, upon a massive of the same character at the same place. The clastic portions

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of the greenstones vary to more silicious rocks, constituting great thicknesses of graywackes, phyllites and conglomerates, and as such have been converted by widespread metamorphism into mica schists and gneisses, the alteration coming on by degrees, increasing in intensity toward centers of granitic intrusion, and toward the great areas of granite and igneous gneiss.

Such granite and such metamorphic rocks, as a whole, have been considered the basement rock, the oldest known rocks of the country. But, following up the long known fact that the Laurentian granite and igneous gneisses cut the schists and sedimentary gneisses and hence are younger, they are in the same way shown to be younger than the bottom greenstones. They occasionally penetrate these greenstones and change them to amphibolyte and pyroxene gneiss. These metamorphic schists and gneisses seem to be a representative of the sedimentary portion of the Lower Laurentian of Canada, while the igneous granite and gneisses are as plainly a general parallel of the igneous portion of that series. It follows therefore that the Canadian Laurentian is, as a whole, of later date than the greenstones, if the succession is the same as in the Northwest, and that the greenstones should be considered the bottom rock of the geological scale.

21. The Origin of the Archean Igneous Rocks. By N. H. WINCHELL. To be published in the American Geologist.

22. Joints in Rocks. By Prof. C. R. VAN HISE, Madison, Wis. (Read by title).

23. Notes on Some European Museums. By Dr. E. O. HOVEY, American Museum of Natural History, New York City. Relating to administration and display of specimens; to be published in the American Naturalist.

24. History of the Blue Hills Complex. By Prof W. O. CROSBY, Boston, Mass. The complex of the Blue hills, on the southern border of the Boston basin, is a small part of the great granitic batholite of eastern Massachusetts, inclosing isolated masses and belts of Lower and Middle Cambrian strata. The Cambrian beds are cut by a series of diabase dikes older than the granites. The granitic series, which clearly constitutes one genetically related or consanguineous group, comprises:

I. Plutonic rocks: 1. Normal granites, forming the main body of the batholite: (a) biotitic normal granite (granitite); (b) hornblendic normal granite. 2. Rocks forming the contact zone of the batholite: (a) dioryte and basic granite (granodioryte); (b) fine granite; (c) quartz porphyry, passing into a basic, quartzless porphyry.

II. Intrusive or dike rocks not occurring as apophyses of the contact zone :(a) microgranite; (b) aporhyolyte.

III. Effusive or volcanic rocks: (a) aporhyolyte (compact and fluidal forms).

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The Cambrian sediments were first strongly folded and injected by the pre-granitic diabase; and quite certainly not later than the early Devonian epochs they were invaded by the great body of magma from which the granitic series was developed. No trace of the floor upon which the Cambrian strata were deposited has been discovered in the region of the Blue Hills complex. It is believed that the granitic magma was, in the main, developed in situ by a great heat invasion or rising of the isogeotherms inaugurated by deep sedimentation and greatly stimulated or accelerated by the thickening of the supercrust by extreme plication and flowage and the transformation of mechanical energy into heat. This heat invasion was sufficient to induce aqueo-igneous fusion in the lower portion of the hydrated zone, whereby the pre-Cambrian rocks and a considerable volume of the overlying Cambrian sediments were absorbed by the plutonic magma. During the slow refrigeration of the batholite and the solidification of the magma, it experienced both chemical and textural differentiation; but the chemical differentiation, whether of the main body of the batholite or of its contact zone, was practically limited to the greatest depths and dependent upon a convectional circulation of the magma, in accordance with Becker's theory of fractional crystallization. In conformity with this view, the contact zone is composed, at successively greater original depths, of quartz porphyry, fine granite, granodioryte, and dioryte, each of these contact types passing gradually downward into the normal granite. After long continued erosion had in large part removed the sedimentary cover of the batholite, crustal adjustments permitted the extrusion of a part of the deep-seated and relatively acid magma residuum, forming intrusive masses or dikes of microgranite and aporhyolyte and effusive masses or surface flows of compact and fluidal forms of aporhyolyte.

This general theory of the complex closely parallels, at most points, that proposed by Dr. A. C. Lawson for the complex of sedimentary and granitic rocks in the Rainy Lake region (Geol. Surv. Canada, Annual Report, new series, vol.iii, 1887-88, F, 139-142).

25. Paleontology of the Cambrian Terranes of the Boston Basin. By AMADEUS W. GRABAU, Boston, Mass. The Lower Cambrian rocks are found to contain fossils at Nahant, Mill Cove, Rowley, Topsfield, and Jeffreys Ledge. The last three localities were discovered by Mr. J. H. Sears, who was also the first discoverer of fossils at Nahant (1887). From collections made by Mr. Sears at Nahant, seven species have been identified, including four of Hyolithes. The fossils detected in the rocks of the other localities consist of indeterminate sections of Hyolithes, and a cross-section of a trilobite from Mill Cove. From pebbles and boulders found at Nahant and Cohasset by Mr. T. A. Watson, a large number of Lower Cambrian fossils have been obtained, representing fifteen species.

The Middle Cambrian of Hayward's creek, South Braintree, contains the large Paradoxides harlani, Agraulus quadrangularis, and

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several other forms. The Upper Cambrian is represented in this district only by erratics containing Lingula and Scolithus.

26. Diamonds in Meteorites. By Mrs. E. M. SOUVIELLE, Jacksonville, Florida.

27. The Periodic Variations of Glaciers. By Prof. HARRY F. REID, Baltimore, Md. (Read by title). The Journal of Geology, in its recent issue for July-August, contains an article on this subject by Prof. Reid (vol. vi, pp.473-476), giving records for Europe, Asia and Greenland, in 1896, and for the United States in 1897. A general retreat of the glaciers is noted, excepting a slight tendency of advance in Greenland.

28. Note on the Occurrence of Tourmalines in California. By C. R. ORCUTT, San Diego, Cal. Near San Diego an enormous bed or vein of lepidolite (lithia mica), 60 feet or more in width where best exposed, contains rubellite (pink tourmaline) in large amounts. As a source of lithia and potash, this deposit must soon take first rank commercially. It is now being worked as an open quarry, and 1,500,000 tons are estimated to be available. Much of the rubellite has been distributed to museums. Tourmalines of gem quality were first found during the present year. Black tourmalines are frequent, but green tourmalines occur only sparingly at this locality.

29. The Agassiz Geological Explorations in the West Indies. By ROBERT T. HILL, Washington, D. C. This paper, which, with several preceding, was presented in Cambridge on Friday forenoon in the Museum of Comparative Zoology (largely founded through the labors and munificence of Louis Agassiz and his son, Prof. Alexander Agassiz), described briefly the expeditions made during recent years by Alexander Agassiz, with his assistants, for observations in zoology and geology, on sea and land, in the West Indies and on the isthmus of Panama. Within late Tertiary and Quaternary time, many parts of this region have undergone great epeirogenic movements, perhaps more interesting than those of any other part of the world in such late geologic periods. A brief outline of the geological work already done and to be done was given, and the conclusion presented that it would take many years of serious research and study before final results could be reached concerning the remarkable history of the region and its relations to continental development.

Dr. J. F. Whiteaves, paleontologist of the Canadian Geological Survey, Ottawa, Canada, was elected to be the vice president for Section E, and Prof. Arthur Hollick, of Columbia University, New York City, to be its secretary, in the Association meeting at Columbus, Ohio, next year. Geology is also represented and honored in the election of Prof. Edward Orton, of Columbus, to be the president of that meeting.

WARREN UPHAM,
St. Paul, Minn., Sept. 19th. *Secretary of Section E, 1898.*

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PERSONAL AND SCIENTIFIC NEWS.

PROF. JAMES HALL, STATE GEOLOGIST OF NEW YORK, died Aug. 7, at Bethlehem, N. H. His long service for the State of New York has rendered his name familiar to geologists throughout the world. His activity spanned nearly two generations, and his impress on geological science is probably greater than that of any other American geologist. The State of New York can well afford to honor herself by some lasting memorial to his name, in addition to that which exists in his published works.

PROF. C. H. HITCHCOCK, having leave of absence from his duties in Dartmouth College, sailed August 25th from Vancouver, on the steamer *Aorangi*, to spend a year in geological exploration in the Hawaiian Islands. His address will be Honolulu.

PROF. W. M. DAVIS, of Harvard University, is also absent, for a year in Europe, his address being in care of Baring Brothers & Co., London.

MR. JAY WOODWORTH, Assistant in Geology, of Harvard University, returned September 17th, from an absence of three months in Europe spent in travel for geological observation, from the Island of Möen, in the Baltic sea, through Germany, Switzerland, northern Italy, England, Scotland and Ireland.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE supplied to its members at the Boston meeting the following handbooks of information: "A Handbook of the Principal Scientific Institutions of Boston and Vicinity, with a brief account of the more important Public Works, of the Geology and Geography, and of Places of Historical Interest" (118 pages, with ten views of buildings, from photographs), prepared by the Local Committee; and a "Guide to Localites illustrating the Geology, Marine Zoology, and Botany of the Vicinity of Boston" (100 pages, with maps, sections, and views), edited by A. W. Grabau and J. E. Woodman, with contributions by Profs. Crosby, Davis, Emerson, Farlow and Wolff, and including convenient bibliographic references. Through the courtesy of the officers of the Harvard University, Cambridge, the Local Committee also presented to the members "A Guide Book to the Grounds and Buildings of Harvard University" (149 pages, with map and many views of the university buildings); and a "Guide to the Peabody Museum" (29 pages).

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GEOLOGICAL PHENOMENA RESULTING FROM THE SURFACE TENSION OF WATER.

By GEORGE E. LADD, Rolla, Mo.

(Plate VIII.)

The term "surface tension" is the familiar one used by physicists to denote certain molecular conditions on the superficial film of bodies, where, owing to the absence of cohesive attraction on the outside, there exists a relatively greater stability of position among its molecules, with reference to movement outwardly from the mass, and a *tendency to diminish the extent of surface*,—a resultant of cohesive forces acting alone from within.

This contractile tendency of the surface is manifested to us strikingly by liquids. In the case of water, among its effects are marked geologic changes, which are accomplished sometimes directly, and sometimes through co-operation with other forces. They will be discussed or referred to here under the general headings: Effects produced by Capillarity; Flocculation; and Floating of Materials.

Effects Produced by Capillarity.

Among the most important results are those attained through the behavior of liquids in minute tubes or fissures: the phenomena being that liquids, within such tubes, stand, under certain circumstances, in positions at variance with those occupied under normal conditions of gravity, or other influencing forces.

These phenomena are omnipresent, and most important

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from a geological point of view, causing the penetration of water, upwards or downwards, or in any direction, into the mineral and rock constituents of the earth's crust, which in the main have a sufficient attraction for water to produce capillary phenomena. But under certain conditions the attraction is wanting and the directly opposite capillary effects are produced.

The principles of the circulation of water through incoherent materials, especially soils, have been comprehensively discussed by Prof. Milton Whitney, in a paper entitled "Physical Properties of Soils in their Relation to Moisture and Crop Distribution," and in other publications.*

Little if anything is added here to his observations concerning the movement of water, through soils. Prof. Whitney, however, applies these principles only to the agricultural question of crops. They may also be considered from a more general point of view and in connection with other phenomena of surface tension of water, i. e. with reference to the relation of moisture in incoherent materials, and the phenomena of shrinkage on drying, to land vegetation as a whole, and to erosion. The broad questions may be asked: How far is land vegetation dependent on capillary waters? To what extent is the presence of soil-mantles dependent upon the tension on the free surface of water acting in capillary tubes?

We know that owing to surface tension a movement of water takes place not only in the more or less incoherent materials, but in the solid rocks themselves, and in minerals along cleavage planes, or wherever a rift or crevice appears, to give play to the necessary forces; Also, that on drying the incoherent materials become more or less hard and consolidated. In studying these phenomena we observe, essentially, *wetness* of the material, and the *continuanee of this condition*, in case of loss by evaporation on any surface, as long as water-supply endures; also that the water is present in minute columns or sheets, and that a *lateral inward pull exists*, on the walls of the rock, varying with the mass of the water suspended in each

*In order to avoid confusion of ideas it is necessary at the start to conceive these materials in a condition *unaffected by the surface tension of water*, i. e., in a *dry incoherent state*, as if removed from water and dried, particle by particle, or ground or produced originally in a dry atmosphere.

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tube. We see further that the effect of this pull may result in the displacement of material, when the conditions are fulfilled in clay or rock dust. In this case the movement of individual particles is accomplished as the mass enters the wet condition, and a *primary shrinkage** ensues, which is followed, if evaporation is in excess of the water supply, by a *secondary shrinkage*, and at least partial consolidation.

Looking upon the average clay as a type of the fine-grained incoherent rocks, we find it to consist of minute mineral particles, most of which are thin, angular scales.

The interstices among these may be regarded as a labyrinth of capillary tubes. The particles have a strong attraction for water, which is absorbed with varying capacities. Such a substance tends also to elevate water from depths below the surface, and to replace that which may be evaporated by the sun's heat. But when the evaporating process is the dominant force at work, drying takes place and *shrinkage of the mass* occurs.†

Our every-day conception of the drying of clays is so intimately associated with the idea of their consolidation and shrinkage, that we are accustomed to think of these as one and the same phenomenon. They are, however, distinct phenomena, the former directly following the application of heat; the latter indirectly consequent upon it through the influence of surface tension.

The nature of this process can readily be seen by a comparative study of the accompanying diagrams.

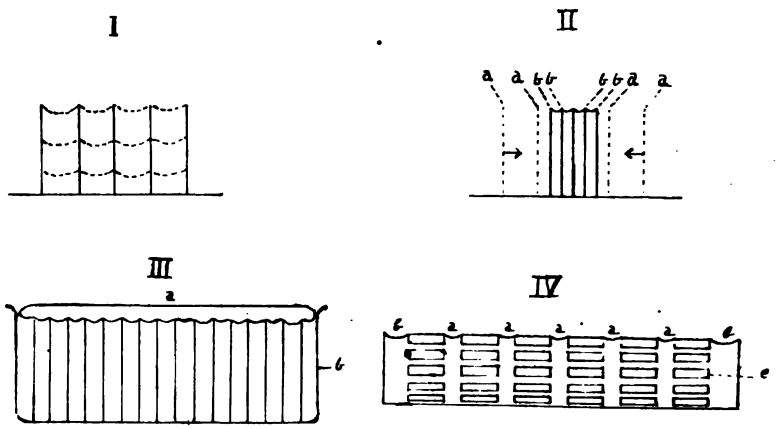
Fig. 1 shows the positions of the surfaces of water in a series of capillary tubes, the walls of which are comparatively rigid and attract the liquid. The dotted lines indicate the positions of the surface of the water at successive stages of evaporation.

Fig. 2 illustrates conditions similar to those in Fig. 1, except that the walls (a) instead of being rigid are collapsible

*The terms primary, secondary and tertiary shrinkage are used by the writer in discussing a series of experiments on clay. They refer respectively to the shrinkage following the application of water to dry or slightly moist clay, (when in the incoherent state); that following drying; and that due to the loss of combined water on ignition or "burning".

†This has a lineal value, in extreme cases, of over 35 per cent.

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and approach each other, as water evaporates, to positions (b), and so on.

Fig. 3 illustrates a thin sheet of water (a) resting on a series of capillary tubes, in a vessel (b) for which it has no affinity. Here surface tension of the water overcomes the pull of gravity.

Fig. 4 illustrates, diagrammatically, the beginning of the process with conditions similar to those in the experiments to be described on another page, (the vessel having been removed from the water supply).

So long as water could be drawn up from below, while evaporation was going on above, there would be no change in the conditions except the gradual movement of water upwards, and no necessary movement of the clay particles in any direction.

When the supply of water is removed, surface tension at (a) and (b) still operates to elevate water to the original hight. If there were no points of weakness in the mass, that is, if the conditions were uniform throughout, and each particle (c) fixed in its place, there would result, of course, only a gradual subsidence of the water. If the particles, however, be considered free to move in any direction, uniform as regards their size, shape and distribution, and if the attraction between the water and the sides of the vessel be exactly equal to that between the water and the clay, a vertical shrinkage will take place.

The capillary attraction capable, originally, of lifting water

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to the points (a), would still be operative, and water, to replace that evaporated, would be fed from the channels, the walls of which are the most easily collapsible, and, with the given conditions, these would be the lateral ones; the downward movement being facilitated by gravity and presence of the one free surface above.

It must be borne in mind, that the tension at the points (a), and beneath them, throughout the process, is of uniform value in each and every tube.

If, as in the case of our experiment, the attraction between the clay and the water exceeds that between the water and the walls of the vessel, a point will be reached where the up-pulling at (a), between the clay particles, will remove the water from the columns (b) adjacent to the sides. The mass is then free to shrink upon itself, in horizontal as well as in vertical directions. Water is fed to the exposed surfaces so long as the particles can approach each other. Shrinkage has been accomplished and a consolidation results from the bringing of the fine particles into intimate contact.

When this takes place in nature the lateral tension is unable to contract the mass as a whole. Owing, however, to inequality of conditions, planes of separation are established along lines of weakness, and "mud-cracks" result. The smaller masses thus formed may then shrink further.

The finer grained the material, the greater the amount of surface of the particles, as compared with their mass. Consequently, there are more contacts; mutual attraction and friction more effective; and the mass more completely consolidated. In the case of sand, the mass of the individuals so far exceeds the amount of surface at which contacts exist, that the bonds are ineffectual, and the material remains incoherent.

The steps leading to these various results may be illustrated by certain experiments, made by the writer while investigating the properties of clays.*

In order to determine the absorbtive power, amount of shrinkage and degree of consolidation of samples of this substance the following methods were employed:

*A more complete description of these is now in press, as a bulletin of the Geological Survey of Georgia.

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1. A weighed amount of clay, dried at 100° C., and previously ground to pass through a 100 mesh sieve, was placed in a brick-shaped tin vessel, the bottom of which was finely perforated and lined with filter paper, to prevent the escape of clay. This vessel was then supported in a small tank supplied with water, just high enough to reach the perforated bottom.

Immediately following the contact of water with the clay, a marked down-pull of the latter occurred, effecting the *primary shrinkage* of the incoherent mass.

2. The next experiment was the determination of the relative rate of loss of water on drying at 100°C., by weighing at fixed intervals; and (3) of the amount of shrinkage for each dimension, by careful measurement at the successive stages of drying. The shrinkage here involved is that referred to as *secondary.*

(4) Other experiments with specially devised apparatus tested the tenacity of the clays at intervals during drying, beginning with the saturated condition, and ending with the dry brick, thus determining the *degree* of consolidation.

These experiments naturally showed results widely varying among the different clays. A brief summary of the more important of them follows.

I. The clays absorbed water in amounts varying, respectively, from 40 to over 200 per cent. by weight.

II. Generally speaking, those, which were originally incoherent in nature, absorbed the largest amounts.

III. The rate of drying varied directly with the amount of water absorbed.

IV. The amount of *shrinkage* varied according to a complex of conditions, such as density, the size and shape of particles of the clay-base, and their state of aggregation, also upon amount of sand present, and the size and shape of its particles.

*The anomalous fact was discovered, that, among clays otherwise similar, those containing the greatest amount of *sand, in cases as high as 40 per cent., shrank the most.* This is noteworthy in view of the fact that sand is often added by potters and brick-makers, to *diminish* the shrinkage of a clay. For the case in hand, however, an explanation may be found in the fact, that the greater part of this sand is in extremely minute particles, probably smaller than those of the clay.

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V. The percentage of secondary shrinkage varied in different directions, being *greatest* for the *smaller dimensions*. The reason for this being, probably, as follows:

The tendency to establish equilibrium in the mass, due to the loss of water on an evaporating surface, is not followed by uniform results, owing to the greater amount of mass to be moved in the longer direction than in the shorter. Consequently the movement and shrinkage are more successful along the shorter dimension. More marked than this, however, as a cause, is the difference in the resistance per unit area of cross section due to the friction on the contact surface, at the bottom of the brick, along the lateral and longitudinal directions. A slender pencil of clay can only be dried without breaking, by resting it on a series of rollers, or some similar device.

VI. The tenacity of the clays varied exceedingly at different stages of wetness.

VII. In general, clays diminishing the most in bulk through secondary shrinkage were, in the dried state, the most tenaceous. For example, one clay having a maximum shrinkage in a single direction of about 24 per cent, withstood a strain of nearly 400 pounds per square inch, while another, with a maximum shrinkage of less than 8 per cent, withstood a strain but slightly over two pounds per square inch.

These laboratory experiments explain the nature of many every-day phenomena in the geological world, where materials and conditions similar to those of the experiments are so constantly encountered. From their consideration we see that the most direct effects of surface tension acting as capillarity in rocks are the *wetting* and *transference of water* through these; *shrinkage* and *consolidation*.

What is the relation of these effects to vegetation?

Surface tension operates to retain rain-water at the surface, where it is available to furnish the moisture needed by plant life, and also to draw up from the "water-table" below, supplies to renew that removed by evaporation and the requirements of vegetation. It carries, held in solution, with the water, the mineral foods which build the tissue and support the growing plants. It also forms a crust produced through shrinkage, which retards evaporation.

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Prof. Whitney in the introduction to "Some Physical Properties of Soils," states that chemical analysis has not explained the relation of soils to plants or the local distribution of the latter; that the *general* distribution of these is determined by temperature and rain-fall, but the *local* distribution, by the relation of the soils to moisture.

If the statements so far made are true can we not reason further, and say that without the operation of surface tension the very existence of land vegetation, or at least the greater part of it, would be threatened? But for capillarity would not rain waters escape through, or over, the soils too rapidly to be available? Would the film of water directly attracted by each grain of soil succeed in resisting evaporation, and if it did, how extensively would it support vegetation? Where would the plant food come from? And another, more fundamental, question,—to what extent would the fine-grained materials, constituting soils, accumulate, and how long would they rest in one place? In short would land vegetation have a soil permanent enough to grow in?

From a consideration of the facts it is evident that the existence of the former, and the permanency of the latter are largely inter-dependent, and that, besides this, each is directly dependent (the degree being the only question) on the operation of the surface tension of water.

If they should dry without the influence of the tension on the free surface of water, they would dry into incoherent "powder," "sand" or "dust," and no crust, more or less solid, would be formed. And, on the other hand, if surface tension did not operate to elevate, in soils, water from below, they would dry after wetting in a much shorter time.

In the former case soils would be subject to erosion to a vastly greater extent than they are, owing to the absence of a crust and the general consolidation shown to result from drying.

In the latter case the presence of the water obtained by capillarity renders the soils somewhat tough and coherent, in a different fashion, and so again tends to retard erosive agencies.

Thus surface tension acts in two direct ways to preserve these materials from erosion—by the wind, the impact of rain, or flowing water.

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Indirectly, it makes possible (?) a growth of vegetation which further and so largely protects the soil from erosion. Moreover, this vegetation is a source of chemical decomposing agents which accelerate soil accumulation—a process further facillitated by capillary penetration of the solid rock.

The following generalizations, though containing familiar facts, are grouped together here as an outline of the features of the circulation of water in soils.*

First—The soils are composed of particles of mineral matter of different sorts, chiefly quartz, feldspar and clay (kaolinite), and these occur in sizes ranging from that of coarse gravel down to minute rock fragments .0001 of a millimeter in dimater.† They are also of different shapes,—the quartz grains varying in form from angular to well rounded, while the clay or kaolinite constituents are commonly present as *thin flat scales*.

Second—The state of aggregation of these, and the relative amounts of each present in different soils, varies enormously.

Third—The attraction of the soil particles for water varies with their chemical nature; and particles of the same material have a varying "affinity," under different conditions (not now well understood).

Fourth—Salts and organic matter, in solution, modify the value of the surface tension of the liquid, the former generally increasing, the latter decreasing it.

Fifth—The circulation of water is of two sorts, viz., (a) flow due to hydrostatic pressure, or gravity, and (b) flow due to capillarity.

Sixth—The permeability of the soil to water moving under the influence of gravity depends largely on the size of the tubes. The smaller the tubes, the slower the rate of flow.

Seventh—The penetration of the soil by water acting under the influence of capillarity depends largely, also, but in a

*For general discussion see Whitney, op. cit.

†In this connection Whitney states the interesting facts; that on the average about 50 per cent of the volume of soils is space occupied only by air and water; that in a cubic foot of soil the grains have, on an average, at least 50,000 square feet of surface; and that soils containing from 10 to 30 per cent of clay consist, respectively, of from four to twelve billion grains.

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reverse way, upon the size of the tube. The smaller the tubes, for a given total area of cross section, the greater the amount of water absorbed, and the higher it is elevated.

Eighth—For a given soil the retention of moisture when loss from evaporation is suffered, depends upon the size of the capillary tubes; the affinity of the soil particles for water; the amount of water supply; and the length of the capillary tubes, or the distance of the "water-table" below the surface.

Ninth—Its retention of moisture when suffering loss through escape below depends, in great measure, upon the size of the capillary tube,—the rate of flow through these for a given amount of pressure varying as the fourth power of the diameter.

Tenth—Soils, sub-soils, and the water reservoir, may all differ in texture. The rate of flow of water to the surface depends largely upon the nature of their texture and the relative positions which they occupy. Further, the penetration of the ground by meteoric waters depends largely upon these same conditions.

Eleventh—Both the presence and the circulation of water in soils depend upon very complex conditions, such as the nature, size and shape of particles; their state of aggregation or the texture of the mass; and the position and amount of water supply.

Prof. Shaler* has called attention to the protection of beach sands from abrasion by the presence of interstitial water held between the particles by capillary attraction.

In another part of the same paper he records observations in connection with sand dunes, where the capillary phenomena appeared to be of a different sort. The observations were that, after a rain-fall of an inch, the dune-sands "would often not be wet for more than three-quarters of an inch beneath the surface," the water escaping to the lower hollows among the dunes, without penetrating them; surface tension, if it be the cause here, acting in a negative way to accelerate erosion by preserving the sand in a dry state.

In view of the effects of surface tension under certain conditions, this phenomenon may possibly be referable to it as

*In a paper presented at the meeting of the Geological Society, December, 1893.

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a cause. In a paper by Alfred M. Mayer,* on "The Floating of Metals and Glass on Water and Other Liquids," it is stated as a result of experiments that materials which will ordinarily attract water, may fail to do so when films of air are condensed on their surfaces, with the result that they will float upon the liquid in question, even when loaded by weights exceeding in value that of the "surface tension" of the given liquid.

If, now, the grains of sand on the surface of the dune be in the condition of the material described above, the attraction between them and the water fails, at least temporarily, to operate. The falling rain drops, larger than the interstices of the sand, immediately coalesce into a sheet, which might remain, through the operation of the tension on its lower surface, a body of water of appreciable thickness supported on the columns of sand penetrating it from below, but not in actual contact with it. (See fig. III.)

Prof. Whitney says, in "Conditions in Soils of the Arid Region," year book, U. S. Department of Agriculture, 1894, p. 160:

> "Water descends very slowly and to a very limited extent in a perfectly dry soil * * * because the tension or contracting power of the surface of the water is greater than the attraction of the soil grains, which tends to cause its diffusion through the mass."

This observation agrees with that made by Prof. Shaler in the field, and with the result of Mr. Mayer's laboratory experiments. Nevertheless, in the experiments conducted by the writer, *clay* dried to constant weight at 100° C. was used, with the result that it absorbed water with extraordinary rapidity and copiousness (in cases, as high as 200 per cent by weight, as stated above). This would seem to indicate that some other condition must be fulfilled than mere dryness, to render the material non-absorptive of water. In fact, while making chemical analyses of clays, and while determining hygroscopic moisture, I have observed that the dry, clay powder would actually gain weight while in a chloride of lime desiccator, even when left there for hours. It did not, however, so gain when sulphuric acid replaced the chloride of lime.

*Science, N. S., Vol. IV, No. 88, Sept. 4, 1896.

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The theoretical possibility coincides with the phenomena as actually observed. This case is the exact reversal, in the position of material, of that of sand floating upon water, to be discussed under another general heading. Here, the water rests, as a sheet, upon a closely packed series of sand columns (not attracting the liquid), and its thickness is limited by the number of these, and by the strength of its surface tension. The phenomenon of the sand dunes may be a capillary phenomenon, though the reverse of "capillary attraction;" and the conditions pertaining in the cases previously discussed, where wetness and an ultimate coherent mass resulted, are also reversed. Surface tension, operating without adhesive attraction, tends to preserve the mass in an incoherent state.

Geologic and physiographic effects result from the comparative rapidity with which such sands are transported by the winds. Prof. Shaler refers to this point and says: "In consequence of this peculiarity of dune sands, which retards their deep wetting in ordinary seasons, they are retained in marching order. So that a strong wind may excavate and bear away large quantities of the material."

A study of sand dunes furnishes a valuable illustration of what would happen to the fine clay and rock dust materials, through wind erosion alone, if they were not consolidated by the processes described.

The phenomena of drying and shrinking may in some special cases, and in a limited way, counteract the general tendency to retard erosion, thus seeming to accelerate it.

"Mud cracks" result, as shown, from shrinkage. The process which forms them may, under certain conditions, accomplish in a local way this relative accelleration, and may effect, in detail, minor physiographic changes.

I have seen very fine examples of this sort of work while making canoe trips down some of our southern rivers, the most beautiful cases being on the Chattahoochee. These occur on both the Georgia and Alabama sides at many points below Columbus, southward to the region of the swamps, near the Florida line.

This interesting stream, within the limits mentioned, traverses a series of strata, consisting largely of clays, marls and sands. For a distance, perhaps, of two hundred miles, it cuts

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through them so as to expose them beautifully in section, its banks being often many feet high.

The singular physiographic feature produced by the force under discussion, is the occurrence of promontory-like projections beyond the vertical banks, over which minor streams, in falls and cascades, tumble into the river.

Since flowing water naturally erodes such materials as marls and clays, I was puzzled to account for the absence of the recess usually found where one stream enters another. It seemed remarkable that a considerable body of water could be precipitated into the river, thereby increasing the destructive force, at the given point, and still produce the effect of locally retarding erosion, that is, leaving little residuary promontories, while the clay walls retreated. But such the phenomena were. The material of the promontory was that of the bank in general, continuous with it, and in no way a deposit by the stream; nor did it appear to be in any case hardened by a local deposition of mineral matter. The explanation sought seemed to be found, in a general way, in the fact that the retreat of the banks was accomplished in part by some other means than the under-cutting of the river, or erosion by rains; and after careful observation a full detailed explanation seemed to be as follows:

(1) Erosion by these lateral streams is at a minimum, owing to the absence in them of transported material, due to their flowing but short distances; and, in the main, across flat surfaces rank with vegetation, which filters out the sediment. (2) The clay material of the bank absorbs by capillary attraction the water precipitated on its surface by night as dew, which falls very heavily in this region. This moisture is then rapidly evaported by day, through the heat of a semi-tropical sun, even though augmented by capillary waters from depths below the surface. The result is a consolidation and shrinkage on the face of the bank, which causes mud-cracks; and since the extreme surface is the first to shrink, there takes place a curling up of the edges of the now isolated patches, and a peeling off, in fragments, of a thin layer of the clay or marl material. (3) Beneath the waters of the lateral stream the clay is continuously in a wet state, and yet, though suffering from the under-cutting of the river and the erosion of the

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falling water, it retreats from the river's edge more slowly than the contiguous bank which is alternately wet and dry.

In short, these "promontories" result from the differential retreat of the banks from the water's edge,—the phenomenon of surface tension leading to accelerated erosion where they are not more or less continuously kept in the wet condition. Of course, a number of conditions must be fulfilled to produce such effects, as,—a suitable climate,—banks of just the right materials and texture,—minor streams, such as drain local swamps, for pure water;—and these conditions exceeding in value the effect of the destructive work of the river in time of flood.

The illustration, Plate VIII, is a view of one of these promontories, taken by the writer from a canoe.* It should be stated that the actual projection of the promontories into the river, as here indicated, is but temporary,—during the period of high water. The line of the bank beneath low water level is continuous.

In spite of my having said that the local erosion suffered is at a minimum, owing to the purity of the water in the minor streams, it must be confessed that they do experience considerable loss from this source. They often have the shape of talus cones, and frequently, owing to differences in the hardness of strata composing them, a series of shelves is formed. The water, falling successively over these, hollows small basins, and I have seen a series of such, carved from the rock, closely resembling those built with deposits of sinter by hot springs. Indeed, the fact that they are sometimes eroded beyond that accomplished by ordinary causes and suffered in common with the banks, but emphasizes the importance of the special acceleration of destructional work resulting from surface tension.

Other effects produced by capillarity are effloresent minerals, occasional ore deposits, some dendritic minerals, etc.

The most important of the efflorescent minerals are the alkali salts in some desert regions, and those brought to the sur-

*They are difficult to photograph, the river flowing very swiftly, and cutting deeply and sharply against the bank, so that a landing where they occur is usually impossible, and it is necessary to photograph them in profile, in order to show their characteristics.

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face on irrigated lands where the water supply is insufficient to establish drainage beneath the surface.

The same process which produces shrinkage and consolidation of clays, under certain conditions, results in the formation of *clay stalactites*. I have seen, pendent from overhanging banks of clay, stalactites which, though comparatively small, resemble exactly in form, the stalactites produced by the precipitation of calcium carbonate on the evaporation of dripping waters in caverns. The first of these seen were collected with the idea that they consisted of some salt soluble in surface waters. Examination, however, showed them to be composed wholly of minute particles of quartz and scales of kaolinite. As opportunity offered the manner of their formation was investigated and found to be similar to that of our ordinary stalactites, except that the whole process is *physical*. Water, percolating through the clay mass above, carries with it some of the finer material, and where points of equilibrium are established between evaporation and supply these interesting forms result, the occurrence of which I have never seen recorded.

Having once observed them, they have since come frequently under my notice. At Rich Hill, near Knoxville, Ga., where a variety of Eocene beds overlie cross-bedded sands and clays of the Lower Cretaceous, a section of two hundred feet is exposed in an immense gully. Here, besides small pendent stalactites, thin wavy ribbons of clay from two to three inches broad are attached, edge-wise, to the sandy walls. Some of them, three feet in length, resemble, in miniature, the "weltberühmten Vorhang" of the Adelsberg Grottoes.

Of the same nature as these occurrences are the thin coatings of clay which wash down from overlying beds, and like a coat of paint often conceal the character of the beds below.

Capillarity does not necessarily enter as a cause, but surface tension operates to contract and to consolidate the particles suspended in the evaporating water.

The main facts, in connection with the action of surface waters in a chemical way are too well known to need discussion here.

Granting that the circulation of water in rock, soils and clays, takes place as outlined above, it follows that the processes which lead to the decompositions and alterations of the

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mineral units of our rocks, and which affect these latter so considerably in the details of their composition and texture, are also directly in part dependent upon this strain on the surface of water.

Flocculation.

The phenomena of flocculation have been discussed by various authors, largely in connection with the subsidence of small particles in liquids. Among these are Hilgard, Brewer, Barus, Whitney, Hunt, Skey, Rawley and Bliss.

The first three named considered the flocculation of such particles and their behavior on the addition of certain solutions as due mainly to chemical action, such as hydration and dehydration. Prof. Whitney, however, and subsequent writers have urged a physical explanation, claiming that the fine particles rendering water turbid are precipitated through flocculation, which results from the altered "potential" of the surface particles of the water, due to the addition of certain salts to the liquid.

If the particles in suspension attract the water more than enough to overcome its surface tension, molecules of water will tend to crowd toward the substance, and such particles will be forced from each other and continue in suspension. But if, on the other hand, these conditions are reversed, the tendency to contract exposed surfaces will operate, wherever possible, to *unite* particles, since this diminishes the amount of such surface. This process increasing the weight of the aggregations relatively much faster than the amount of surface exposed, where friction tends to prevent subsidence, allows them to settle, and leave the liquid clear.

In this manner we account for the sudden subsidence of small particles suspended in rivers, where these enter the salt waters of the sea, which are of still higher specific gravity; and this process must be looked upon as of geological interest if not importance.

Of more significance is the effect of such flocculation upon the *texture* of our soils, which is shown to be so largely modified by the presence or absence of substances in solution that the production of crops, and the power of the soil to support plant life, may be profoundly affected by the use of such solutions, without reference to their fertilizing powers.

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Attention has been called frequently to the function of clay particles in producing the phenomena of flocculation resulting from their diminutive size, stress being laid upon the fact that as bodies decrease in size the extent of surface rapidly increases relatively to the mass.

There is a point, however, of equally great importance, viz., that the *shape* of the particle can *almost indefinitely* extend the relative amount of surface. Thus, for a given mass, angular particles expose more surface than spherical ones. The surface of spherical bodies varies as the square of the diameter, but if the particles be flat, the surface can be increased relatively to mass, by change of shape (theoretically), until the molecules of the substance all lie in a single plane. As a matter of fact most minute mineral particles are generally angular rather than rounded. Kaolinite, however, the essential mineral of our clays, and so omnipresent, commonly occurs in the form of thin cleavage plates. It is thus probable that the diameters measured by Prof. Whitney for his calculation on the amounts of surface exposed in different soils were often the greatest diameters of flat particles, and consequently the amounts of such surface would be even greater than that indicated by him in his reports.

Floating of Materials.

It is not uncommon to see materials of a higher specific gravity than water floating upon its surface.

The principle involved is again that of surface tension, and substances thus float only when attraction for the water is less than the value of the latter's surface tension.

The geological results of this principle are chiefly the floating and shifting from place to place of sands. While I have observed such an occurrence on many occasions, in different places, the most important noticed was in Massachusetts, at the mouth of the Merrimac river. Here the northern end of Plum island, which is a vast accumulation of sand, shuts in the harbor of Newburyport on the southeastern side. The action of the winds, of the waves, in time of storm, and of the shifting currents (the position of the harbor's channel varying rapidly) result in the formation of numerous bays or "basins" in the sandy island, on the protected side, often oc-

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cupying extensive areas. The largest of these, having a circumferance of something over a mile, has endured for the past forty or fifty years. The sand consists mainly of coarse, sharply angular quartz, but much feldspar is present, some mica and numerous fragments of schistose and gneissic rocks. Whenever, on the retreat of the tide, the beaches and the exposed bars are dried by the sun's heat, the returning water, if not too greatly disturbed by unfavorable winds, lifts as it creeps up the slope, the whole superficial film of sand, including large thin pebbles of schist, and floats it gently away on its surface. The surface of the water, near the shores bearing the sand, commonly moves out toward the main river, even when the tide is rising, the incoming water flowing beneath.

I have estimated that in the course of a year something like a thousand tons of sand, at a minimum, are lifted and borne away to new resting places by the floating power of surface tension at this locality alone. This is, of course, however, an insignificant factor in the general distribution of the sands, as compared with the waves and currents, which sometimes move acres of these materials to a depth of from twenty to seventy-five feet in a few hours. The phenomenon of the natural floating of sand on water has been recorded by J. C. Graham* and by F. W. Simonds.†

The surface tension of water together with the mutual attraction which usually exists between its molecules and those of clay and rock minerals, is a factor profoundly affecting conditions on land surfaces. It accomplishes the shrinkage and consolidation of clays and rock dust. It facilitates the decomposition of rocks and retards the removal of the products of decomposition to an enormous extent, although in exceptional cases and under certain peculiar conditions it acts locally to increase erosion. The existence of land vegetation is directly dependent upon it. It is responsible for the occurrence of many efflorescent and dendritic minerals, and some ore deposits, and it constructs, of clay, stalagmites, stalactites and coatings on other rocks. It hastens the subsidence of fine particles where streams and rivers enter the ocean, and further causes the removal of coarse sand and

*Am. Jr. of Sci., III. Vol XL. P. 476, Dec., 1890.
†Am. Geol. Vol. 17, No. I, P. 29, Jan., 1896.

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thin flat pebbles on the surface of water in which they could not be transported if immersed, a fact which may explain the presence of scattered grains of coarse sand in beds of fine clay.

The occurrence as seen by Mr. Graham was the removal and floating away of sand by gentle waves, splashing against the bars along the margin of the Connecticut river.

Prof. Simonds describes his observations on the Llano river, in Texas, where dry sand was gently fed to the surface of the water by an undermining process. He explains it vaguely as a phenomenon of "superficial viscosity."

THE OCCURRENCE OF COPPER AND LEAD IN THE SAN ANDREAS AND CABALLO MOUNTAINS.

By Pres. C. L. Herrick, Albuquerque, New Mexico.

A somewhat interesting occurrence of copper in the mountain chain lying on the east side of the Rio Grande valley may be most easily understood from the conditions in the San Andreas, which lies some ten miles east of Lava station south of Socorro. The railroad here seems to pass through a syncline as the exposures of Carboniferous near the river dip to the east while the strata in the Andreas dip towards the northwest. To one approaching them from the east, that is from the plain of the white sands, the mountains present a rather abrupt escarpment rising nearly directly from the plain. The face is cut here and there by valleys and canons, but the configuration and geologic structure are remarkably uniform. The lower part of the scarp is composed of granite, gneiss or quartzyte of the metamorphic series and in this respect the conditions are precisely as in the Sandias and elsewhere in the ranges bordering upon the Rio Grande. Above this granite base rises the stratified series composed of Carboniferous limestone and interbedded sandstones with a thickness of 600 to 700 feet. In lithological and paleontological character this series presents no noteworthy peculiarities, but it differs from the similar exposures further north in the fact that the entire limestone series is cut by nearly vertical veins of considerable

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size which run about at right angles to the strike. These veins are numerous and occur at irregular intervals of a quarter to half a mile or more, and are so conspicuous that a number of them can be seen from the plain as depressed or elevated bands crossing the strata. The thickness of the veins varies also but many of them are from five to twenty feet thick and are filled with the most diverse materials. Some are silicious while others carry fluor spar, calcite, siderite, baryta, etc. While the veins can be traced to the contact with the granite they do not penetrate it, or if they do, it is only in the form of a narrow fissure. It would appear that the flexure which produced these fractures had more effect on the stratified than on the metamorphic rocks or that subsequent warping chiefly affected the upper series. At the juncture of the Carboniferous limestone with the granite there is often a thin band of red sandstone which has served to catch the leechings from the entire series above. Thus it happens that there has accumulated a band of hæmatite at this contact which is sometimes quite pure by substitution, but, in the majority of cases, is simply composed of a coating of the oxide covering the original quartz grains so that, when broken, every individual grain of the apparently oolitic ore is found to contain a quartz nucleus. Mining men have been deluded by this appearance into the attempt to use such material for iron flux; actually adding a rock with about 80 per cent silica to an ore requiring iron to assist in removing the excess of silica.

A very hasty glance at the situation is sufficient to explain the method of precipitation and segregation of the copper ores. The latter consist of copper glance, malachite, cuprite, and, in fact, nearly all the common ores of copper mixed with siderite and hæmatite and gangue matter. The sulphides of copper and associated silver must evidently have come in from below, rising possibly, in the circulating water, and it is equally plain that the iron band has accumulated by leeching from the superposed strata. At the lines of intersection and in the presence of air the precipitation has taken place. Comparatively little of the sulphides has collected below the contact (iron) zone and very little has passed beyond the iron zone to any great distance. It also appears that there is a diminution of the deposit at a distance from the surface.

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The showing at the intersection is often very good and has been the cause of a great deal of profitless investment. It is possible to point out the places where such deposits will be found without doing more than to stand at a distance and note the points of intersection of the veins and the iron band so that the geologist gets credit for a great real of acumen for a prediction which is based wholly on a very simple metallurgical principle.

The region described extends many miles along the eastern slope of the San Andreas and similar conditions occur elsewhere. It is true that a considerable amount of fine copper ore occurs in these intersections and, with better means of access, they will no doubt be utilized, and it is also true that there may be found deeper workings where under different conditions of accumulation large bodies of good ore might occur, but the careful investor will avoid being deceived by the surface showing and will beware of too general application of the miner's notion that mineral must "go down."

The Caballo Mountains. Between the San Andreas and the Rio Grande is a large stretch of desert plain called the Jornada del Muerto which, from the lack of water, has long been a terror to the freighters and packers. Much of pioneer romance has been woven into stories of the Jornada and even since the railroad has bridged the gulf it is still unreclaimed. Toward the western border of the plain there is a series of basaltic cones from which there spread out over the plain larger or smaller sheets of lava, the most northern of which, at San Marcial, extends to the river. At this place the lava flows over a deposit of sand and stratified loam not unlike that west of Albuquerque. This series of basaltic flows is a continuation of that further north in the valley but the river at this point has been diverted to the west. The occasion for this diversion is apparently the elevation of a minor axis on the western border of the Jornada forming the San Cristobal and the Caballo mountains, in Sierra county.

Both these ranges rise quite abruptly from the eastern edge of the river valley to a variable hight. The Caballo range is the higher and is that with which we at present have to do and is mentioned in this connection to illustrate the modification of the same method of precipitation as that seen in the

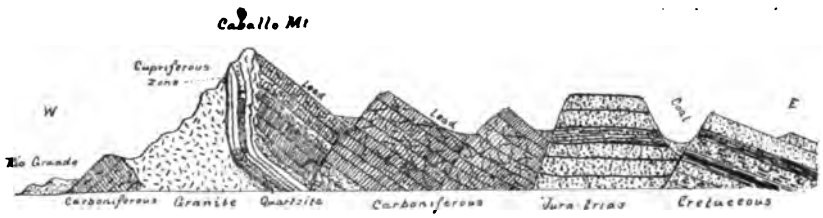
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San Andreas mountains. The western escarpment is for the most part very steep with evidence of very considerable metamorphism. The very axis of break in some places is preserved and affords very interesting illustrations of what can be done in the way of altering a limestone by the agency of mechanical friction and pressure without the presence of a source of igneous heat. So far as seen, there is no intrusive in this range but the displacement along the axis of uplift was very great and the area affected was quite narrow. The sequence of the strata seems to have been about the same as elsewhere in the valley although opportunity was lacking to make a sufficient examination of the lower as well as some of the higher strata at points where the absence of excessive metamorphism would admit of expecting organic remains. The fossils seen from the upper part are such as are found in the upper three hundred feet of the Carboniferous in Bernalillo Co., the abundance of Bryozoa being quite characteristic. Below the middle there are shaly beds in which are found the same facies which occurs in the lower parts of the series as exposed in Socorro and Bernalillo counties but the lower one hundred feet is so altered in all the places visited that it is impossible to deny the local belief that it contains some strata of an age earlier than the Carboniferous. However, it may be said that there is no evidence of unconformity in the series where undisturbed and there is nothing in the lithological character of this portion to dispose one to regard it as other than the sandy lower part of the Carboniferous as seen elsewhere in the valley. Such fossils as *Chonetes mesoloba*, *Spirifer opima*, *Martinia lineata*, *Aviculopecten carboniferus*, *Terebratula sp?* *Productus cora*, *P. nebrascensis*, in the lowest fossiliferous beds examined and certainly below the middle of the series permit us to expect that the lower parts will prove Carboniferous.

The foot of the western slope is granite, gneiss or schistose rock of a somewhat nondescript character, varying from place to place and much mingled locally along the axis, which, while in general trending north and south, has many local offsets and irregularities. Above the granite is a band of quartzyte as usual, the thickness being little more than twenty feet. At the contact with the limestone series is a coarser phase which from its position immediately above the impervi-

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ous stratum formed by the granite, becomes the collector of the iron leeched from the rocks above, forming a band of variable width in which the sand grains are coated with iron oxide or replaced by it. In this case the collection is not so complete at this horizon as in the San Andreas by reason of the fact that the metamorphism of the sandy lower layers of the limestone has been so complete as to form water-bearing horizons above, and there has been a good deal of accumulation of iron in the same way at these higher levels. Along the axis of uplift the effect on the silicious materials has been very great, and there has been a thickening of these bands. The lime, on the other hand, has been abruptly turned on edge and the selvedge has been wedged in between the less altered lime and the granite till from a distance it appears in sections as though there had been an igneous intrusive thrust up at this point. Such an appearance is very deceptive in the section in the Palomas Gap canon and affords a most interesting geological object lesson. The general conditions are reproduced in the accompanying diagram.



The whole series is subject to the same system of fracture lines so much in evidence in the San Andreas and the collection of copper at the intersection of the veins with the iron band is similar, with this difference that, inasmuch as the iron is also to some extent precipitated in the lower members of the limestone series, the sulphides are also more extended in the vertical direction. This fact will also probably militate against the collection of very large bodies even at the intersection. The chemistry of the copper precipitation may well be a subject for speculation. That the iron is leeched from above can hardly be doubted and it is equally probable that the copper came up in some form from the depths along the fissures. It is obvious too that no considerable part of

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the copper has been precipitated in the granites or in part of the lime not within reach of the iron. It may be that the action of the air-bearing water near the surface tended to liberate sulphurous oxide and that an iron solution thus formed in the vicinity of the ore of iron produced the necessary conditions for precipitation, very much as they are supplied in certain leeching plants for the treatment of copper.

On the east side of the mountain near the axis, the lime is much tilted and is also disturbed in the direction of the strike of the range. In fact, the disturbances are of the most profound nature, yet the dip in general is sharply to the east and the limestone is minutely veiny. These veins are filled with fluorite, barite, quartz, and calcite and may also carry certain, or rather very uncertain, quantities of galena and, in some instances, wulfenite.. One or more faults parallel to the range repeat the strata toward the top of the formation in the successive foot-hills to the east and in these the metamorphism has been less intense and the veins are not quite so numerous. The larger ones cross the strata in, or nearly in, the plane of the dip and are sometimes quite large and in such cases often carry large quantities of galena in a barite gangue. In general, however, the veins give off "feathers" extending for fifty to seventy-five feet and these collateral veins are quite as likely to carry lead as the main vein so that the total amount of ore is difficult to recover. The commercial concentration of ores rich in heavy spar at a distance from water and fuel becomes an economic problem of as much difficulty as interest.

The time may doubtless come when nature will accomplish the concentration of the lead in much the same manner that it has done it in the Magdalena mountains and elsewhere where the sulphide, after having been altered to the sulphate is precipitated as a carbonate. That this process is in progress is shown by the fact that in the more exposed parts of the workings upon the veins the galena is quite extensively removed, and in parts not removed it is partly changed to sulphate. To determine in advance the secret chambers where the percolating waters will find the conditions for the reprecipitation of lead is beyond our power and this legacy to the future must be left to the future to recover.

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Following the Carboniferous limestones is a series of very red sandstones and shales which is not shown in conformable relations to the lime but is seen in the ridges to the east of the latter lying with a much less sharp dip to the east. It may be that these beds, three or four hundred feet thick, are supported by Carboniferous strata but the contact is not exposed. No fossils except the trunks of trees have been found but from the lithological character, position and from general analogy they may be supposed to represent the so-called Juratriassic of other parts of the territory.

Following these red beds are the grey sand-stones and dark shales of the Cretaceous. It is impossible to determine the thickness of this formation but it is undobtedly extensive and, after forming the numerous ridges east of the red beds, the strata become less inclined and extend indefinitely to the east and are in places capped by the lava beds. Two rather small beds of coal are found in the lower part of the Cretacous as here exposed. The paleontological evidence is fairly complete but has not been sufficiently examined. Beds of Ostreas occur in the shales not far from the coal and in these the shells are well preserved.

[European and American Glacial Geology Compared. X.]

GIANTS' KETTLES NEAR CHRISTIANIA AND IN LUCERNE.

By WARREN UPHAM, St. Paul, Minn.

The glacial rivers recorded by eskers belonged to the time of departure of the ice-sheet. Any very long esker was not deposited wholly at once; or, in other words, contemporaneous origin cannot be affirmed for different parts of its extent. Its formation took place in the peripheral, stream-channelled margin of the ice; and it grew in length, up to 100 miles or more in some instances in southern Sweden, as also in Maine, being deposited progressively from south to north, as the continental glacier retreated. The steepness and frequently crooked courses of the eskers prove that they were not overridden by the ice-sheet to which they owed their origin, nor by any later glacial reädvance. Probably their material was

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washed away from superglacial drift, exposed by ablation, mostly within ten to twenty miles back from the edge of the ice, and at altitudes ranging from 50 or 100 feet to 1,000 feet above the land. To such altitudes we may believe that drift was borne upward into the basal part of an ice-sheet a mile thick, if we may draw a proportional estimate from the Malaspina glacier of Alaska, and from the observations by Chamberlin, Drygalski, and others, concerning the plentiful englacial drift in the lower part of the terminal cliffs of the Greenland icefields. Moreover, in the esker of Bird's Hill, near Winnipeg, Manitoba, I have found conclusive proofs that much englacial drift, becoming at last superglacial, existed there at hights exceeding 500 feet.

Another evidence of glacial rivers is supplied by water-worn pot-holes, called in German and in the Scandinavian languages "giants' kettles," which were bored in the bedrock beneath glaciers or an ice-sheet by torrents of water falling through deep moulins. This name, moulin, coming from the French and meaning a mill, is applied to a vertical tunnel, melted at first by the waters of the surface trickling into some very narrow crevasse that has just begun to open, until, after enlargement by this dissolving action, it receives sometimes a large stream, such as could not be waded, pouring with a thunderous roar down a cylindric shaft to the rock floor under the ice. The esker rivers belonged to the closing stage of the Glacial period; but the torrents eroding glacial pot-holes in Scandinavia, Switzerland, and the United States, appear, as will presently be explained, to have attended the accumulation of the ice-sheets. The streams that bored these pot-holes or giants' kettles were very small, and were only very scantily drift-laden, in comparison with the rivers which formed the great esker ridges.

In the close vicinity of Christiania, Norway, numerous giants' kettles have been discovered and cleared of the glacial drift and water-rounded stones which filled them. The locality of greatest interest is Kongshavn, a southeastern suburb on the shore of the Christiania fjord, where, between the lines of low and high tide, a glacial pot-hole eroded in gneiss was found, on the removal of its drift contents, to be 16 feet deep, with a diameter of 5 feet. Another pot-hole, from which the

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drift was excavated under Prof. Kjerulf's direction, measures 34 feet in depth on one side and 44 feet on its higher side, having a nearly cylindric but somewhat spiral or rifle-like form, 8 to 12 feet in diameter. The altitude of its mouth is 90 feet above the sea.*

Taking up the question of the probable epoch or stage of the Ice age in which the Christiania giants' kettles were eroded, we are confronted by the occurrence of marine shorelines and shells in deposits overlying the glacial drift, which demonstrate that during the time of the glacial recession there the land was depressed about 600 feet below its present hight. It is impossible to ascribe the moulins and pot-holes to torrential agency beneath the sea level, and consequently they must belong at Christiania to the earlier time of high land elevation and snow and ice accumulation.

Our Scandinavian travels ended in the journey along the Denmark peninsula as described in the sixth paper of this series; and thence we passed, in a very busy week, through Hamburg, Berlin, Dresden, Prague, Linz, and Salzburg, to a Sunday's rest, August 8th, 1897, in Bischofshofen, a most quaint alpine village, which was our railway junction for the next day's journey through Tyrol, by Innsbruck, to Zurich. On Tuesday morning we took the earliest train to Lucerne; and, after a few hours spent in a visit to the Glacier Garden, sped onward, by railway and steamer, over the Brünig pass, into the upper Aare valley, to Meiringen, Brienz, Interlaken, and Grindelwald. The next day was occupied in excursions to the lower and upper Grindelwald glaciers,† and in climb-

*"Giants' Kettles at Christiania," by W. C. Brögger and H. H. Reusch, in Quart. Jour. Geol. Soc., London, XXX (1874), 750-771.

†NOTES ON THE GRINDELWALD GLACIERS.—The lower glacier has retreated about a third of a mile, and the upper glacier about a sixth of a mile, during the last thirty or forty years, as is known by the scantiness of vegetation and the absence of bushes and trees on the somewhat semicircular areas so lately laid bare. The drift of these areas is largely waterworn, but much typical till or ground moraine is visible closely adjacent to the present end of the upper glacier.

We went about 200 feet into the upper glacier in a passage cut for visitors, and at its end observed the granulation of the ice, a candle being kept burning behind a detached block to display this structure. The granules are of varying size up to 1½ inches long, fitting together with sharply defined and angular boundaries, as figured by Deeley and Fletcher (Am. Geologist, vol. XVII, pp. 16-29, Jan., 1896, with a plate which shows sections of glacier ice, its figures 2, 4 and 5, being from this glacier).

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ing high up on the grassy mountain opposite these glaciers for its glorious view of the snowclad Bernese Oberland mountain range, culminating in the Finsteraarhorn and the Jungfrau. Thus far our few days in the Alps had been favored with the most beautiful weather; but Thursday brought rain, in which we went onward to Bern, visiting its very interesting historical and archæological museum, cathedral, clock tower, and bears' den, thence continuing in the clearer afternoon to Lausanne, with its magnificent prospect across the lake of Geneva. On Friday we regretfully left Switzerland, and passed through the Jura ranges and by Dijon to Paris. Instead of less than a week, I would again spend a month or two, or a year, amid this grand Tyrolese and Swiss country, the playground, resting-place, and sanitarium of Europe.

Excavation in the glacial drift for a cellar, in the year 1872, first revealed a part of the very admirable group of giants' kettles which is now one of the chief attractions of sight-seers in Lucerne. This town itself is in many respects the most fascinating one for tourists in Switzerland, and the most convenient for many neighboring excursions, as to Mts. Rigi and Pilatus, and the sail on the wildly picturesque and historic Lake of the Four Forest Cantons. The Glacier Garden is about 100 feet above the lake, and is only a few steps from the Lion Monument designed by Thorvaldsen, which was chiselled from the solid rock fifty years earlier (in 1821). Thirty-two pot-holes of moulin torrent erosion are inclosed in the Garden, occurring irregularly grouped upon a remarkably furrowed, waterworn, and glacially striated rock area about eight rods long and four rods wide, which was originally so drift-covered that its wonderful torrential and glacial sculpture was concealed. The covering of soil and drift has been removed since 1872, and many rounded stones, which served as grinders rapidly whirled around by the falling waters, from those of small size up to others of huge dimension, five feet or more in diameter, have been removed with the gravel, sand, and clay that filled these rock kettles.

A very interesting rock cañon, which was subglacially eroded by the large stream flowing from the lower glacier, is now exposed by its retreat along a crooked course of about 1,000 feet. The cañon is mainly about 150 feet deep, and varies from 15 to 100 feet in width, except that it is in part narrowed and closed above, along a distance of about 200 feet, by movement of the rock walls, originally separate but now in contact.

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The largest pot-hole of Lucerne, on the northwest border of the group, has a diameter of 26 feet and depth of 31 feet. Its southern side overhangs, probably because the northwardly flowing current of the overlying glacier carried the moulin slightly forward while the rock erosion was taking place. The movement was least at the base of the glacier, and increased differentially upward. The moulin therefore became inclined, and discharged its torrent somewhat backwardly into the rock kettle, hollowing it thus with an overhanging wall. The same feature is observable in several others of these pot-holes, and many of them display spiral wearing. In some instances the pot-holes have irregular and composite forms, showing apparently that successive and independent moulins, probably of different years, contributed to their erosion. They range in size from the largest to others 9 or 10 feet deep and 4 or 5 feet in diameter, and to small cylindric or hemispherical kettles only one or two feet deep.

It is also to be noted that the rock at two or three places is waterworn in broad and somewhat crooked grooves, varying in depth to six or seven feet, and extending 20 or 30 feet in length, where the moulin torrent was less concentrated and more variable than usual; or, more probably, these grooves may have been made by a very inclined and powerful englacial and subglacial stream there impinging on the rock floor. Perpendicular pot-holes of the usual form, but of small size, occur occasionally in the grooves. It is especially noteworthy, both here and in other localities of Europe and America, that generally the edge or lip of the giants' kettles, whether large or small, is abruptly cut in the rock surface, perhaps sometimes because of their partial removal by glaciation subsequent to the moulin erosion. They seldom have a flaringly curved mouth, such as more frequently characterizes pot-holes seen at the present time in the process of erosion by cascades in brooks and rivers.

Rock exposures adjoining giants' kettles are often unmarked by other waterwearing; but in every present stream having falls and eroding pot-holes, larger spaces are irregularly worn and channelled. The rock kettles of moulin formation, found where no stream now exists nor can be supposed to have ever flowed except when the country was ice-enveloped,

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are the predominant or the only form of water erosion in their vicinity; but at the falls of ordinary streams, pot-holes are exceptional, or a subordinate feature, among more extensive grooving and other fantastically waterworn sculpture. It is evident, too, that glacial planation, ensuing after the moulin origin of the giants' kettles, although probably in many places effective to intensify this contrast, cannot generally be its chief explanation, which is rather to be found in the protection afforded by the ice covering the rock contiguous to the base of the moulin. The rebounding water, indeed, welling up from one side of the rock kettle, may perhaps have usually flowed away, for its immediate exit, in an englacial tunnel, or at least with some drift between it and the rock. The conditions of erosion of the giants' kettles prevented or minimized contiguous waterwearing, which, on the other hand, is favored and predominant wherever pot-holes are made by subaërial streams.

In Vermont and New Hampshire pot-holes have been observed by Profs. Edward and Charles H. Hitchcock, and by the present writer, in localities where they must be referred to the Glacial period. Sometimes, on hills and mountains and on lake shores, they were undoubtedly due to moulins; but in several instances they occur at cols over which the outlets of ice-dammed lakes appear to have passed.* On the seashore in Cohasset, Massachusetts, subglacial pot-holes have been described and figured by Mr. T. T. Bouvé;† and numerous others of similar origin are known in that state, but await publication. Indeed, they are of frequent occurrence, but mostly remain undescribed, throughout the entire glaciated region of the United States and Canada.

The most remarkable known of these giants' kettles, whether we consider their size or the manner of their occurrence and discovery, are two found in 1884 and 1885 in Lackawanna county, Pennsylvania, about three miles northwest of Archbald. As described by Mr. C. A. Ashburner, the Archbald pot-holes are 1,000 feet apart and were both discovered in

*Geology of Vermont, 1861, pp. 216, 930; Geol. of N. H., vol. III, 1878, pp. 64-66, 249.

†"Indian Pot Holes, or Giants' Kettles of Foreign Writers," Proc. Boston Soc. Nat. Hist., XXIV, 1889, pp. 219-226; with discussion by Warren Upham, pp. 226-228.

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coal mining, their bottoms being in the coal bed. When the drift filling the one first discovered was cleared out, it was found to be 38 feet deep, with a diameter of about 15 feet at the bottom, increasing to a maximum of 42 feet and a minimum of 24 feet across its top. The second pot-hole, of similar basal diameter in the coal bed, had not been cleared of its drift contents; but it is known from the levelling and test-pits or borings of the mining company, to have a depth of about 50 feet in the rock, with a covering of 15 feet of drift above.*

According to these observations and records of glacial pot-holes, in their best known localities of both Europe and America, it seems to me most probable that the time of their excavation in nearly all cases was the early part of the Glacial period, or some stage of glacial extension, when the ice-sheet was being formed upon the land by snowfall. On any hilly country the ice must have attained an average depth somewhat exceeding the altitude of the hills above the adjoining lowlands before any general motion of the ice-sheet could begin. During the process of slow accumulation of the ice-sheet, the summer melting upon its névé surface would produce multitudes of rills, rivulets, and brooks, which might unite into a large stream, and this, pouring through a crevasse and melting out a cylindric moulin, might fall perhaps 100 or 200 feet or more on a moderately hilly region, but probably sometimes 500 feet or more on a mountainous district, while yet the ice motion, though sufficient to permit the formation of the crevasse, might not have gained a definite current to carry the crevasse, moulin, and waterfall away from the spot where they were first formed. We may thus explain the continuation of a glacial waterfall in one place while it was excavating one of these giants' kettles. After the ice-sheet acquired a current because of the greater thickness and pressure of its mass, such deep cylindric excavations in the bed-rock could not be made; and during the recession and final dissolution of the ice-sheet it seems probable that its receding border had steeper gradients and consequently even more

*Geol. Survey of Pa., Annual Report for 1885, pp. 615-625, with a map, sections, and two plates (views from photographs of the first pot-hole when cleared out for use as an air shaft.)

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rapid motion than during the culmination of the Glacial period. Moreover, the streams formed on the surface of the ice-sheet by the summer melting before it was so thick as to have motion would be free from drift, so that they could readily find their way through crevasses, wearing pot-holes in the rock beneath, and thence flowing in subglacial courses; but, on the contrary, the superglacial streams during the departure of the ice, which then became more or less covered with the previously englacial drift, laid bare by ablation, were heavily freighted with the gravel, sand, and clay of the modified drift, which must have soon choked up the passages wherever these drift-laden streams found crevasses, causing them to flow in superficial channels walled and underlain by ice, until, near their mouths, the ice was melted through to the ground and kames and eskers there received the coarser parts of the rivers' burden.

The rate of erosion of the giants' kettles, referred to a stage of incipient glaciation, and the rate of formation of kame knolls and hills and esker ridges during the wane of an ice-sheet, were surprisingly rapid, in comparison with the generally very slow rates of geologic action. Watch the artificial processes of granite and marble abrasion and polishing, and there will be no need to doubt that the largest rock kettle of Christiania, Lucerne, or Archbald, could be hollowed out during the warm months of even a single year by a stream 20 or 50 feet wide and 2, 3, or 5 feet deep, falling down a moulin 200 or 500 feet deep, and well supplied at the bottom with grinding boulders of granite and other very hard rocks. Crevasses and moulins would be formed in successive years at nearly the same situation, thus producing such a profusely kettled surface as in the Glacier Garden.

Much later, if the retreat of the icefields under ablation was so rapid as a tenth of a mile yearly, apparently its rate near Stockholm according to observations noted in the preceding paper of this series, or about half a mile each year during centuries, as was probably true of the area of the glacial lake Agassiz and the vast plains of the Saskatchewan and Winnipeg country, we cannot doubt that the most massive eskers, as in Sweden, and the highest kame hills, as the

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Devil's Heart hill, 175 feet high, in North Dakota, could be formed within a few years for any single section, or perhaps even within one summer for the great kame mentioned. Some of these gravel-depositing rivers, as shown by the widths of esker ridges and plateaus, were two to five or ten times larger than those of the moulins and rock kettles.

THE ORIGIN OF THE ARCHEAN IGNEOUS ROCKS.

By N. H. WINCHELL, Minneapolis, Minn.

It has been shown by the writer in a previous paper* that the greenstones of the Archean are the oldest known rock, and may safely be considered, in our present state of knowledge, as the existing representative of the original crust of the globe. This, of course, leads to the necessity of admitting that the primordial magma was a ferro-magnesian one, at least so far as it existed at the surface of the cooling globe, and it would be also reasonable to admit that igneous rocks of later date, having the same composition, were derived from the same magma from deeper points within the earth. With this for a point of departure, it becomes necessary to inquire into the origin of the alkaline magma which gave rise to the granites and igneous gneisses.

It was likewise shown in a previous paper that the granitic magma made its appearance amongst the rocks of the earth at a later date than the ferro-magnesian, since the oldest alkaline rocks occasionally intrude into the oldest ferro-magnesian.

These two types of Archean igneous rock may be accepted as the dominant great facts in Archean vulcanology, and all subordinate facts may be considered as attendant and accidental, but yet legitimate, consequences of the reign of these two. This statement necessarily covers the occurrence of igneous rocks of intermediate characters. They must be considered as in some way dependent on the leading role played by the greater agents, and as unimportant in a fundamental inquiry into the origin and mutual relations of those greater agents.

*Am. Geol. Oct., 1898, p. 262.

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It is a curious and interesting fact that, while numerous geologists, and especially T. Sterry Hunt and Michel Lévy, reached the conclusion, on chemical and speculative grounds, that the first crust of the earth was a ferro-magnesian rock, only in recent times has it been possible to refer directly to that old crust as at present existing and susceptible of examination. On all hands it has been assumed that the oldest known rock was an acid one, represented, in Canada, by the fundamental or Ottawa gneiss, which, being an alkaline-acid rock, has been supposed not only to represent the earliest magma, but the starting point in a period of magmatic differentiation. It is necessary, on the other hand, if the greenstones express the character of the earliest magma, to reverse the process of differentiation, and to seek some way of producing the alkaline-acid magma from the ferro-magnesian.

These extremes of differentiation, or at least of difference, present remarkable contrasts when considered from a chemical point of view, the most noticeable of which is the occurrence in one of certain elements which do not exist in the other, or exist in but small amounts. The "crenitic hypothesis" of Hunt was intended to explain how all the crystalline rocks, both acid and ferro-magnesian, could be derived from the earliest magma, by a long-continued process of lixiviation by circulating waters. Such waters were supposed to have brought the elements of the early magma to the surface of the earth and to have deposited them under circumstances favorable for their consolidation into all the varied rocks of which the Archean consists. Hunt entered into an extended survey of the secondary minerals of rocks, and an investigation of their methods and sources of generation. He found that in a manner satisfactory to himself, all the minerals of the alkaline magma can be explained as derivatives from the ferro-magnesian magma, at least in small amounts. By this extended lixiviation Hunt believed that the original crust of the earth was wholly destroyed, or at least was deeply buried under its own ruins, and could not be anywhere identified. The greenstones, which, as stated, are the base of the series, he put into the "Huronian," and their production he considered the last step in the process.

Recalling, now, the principal chemical characteristic of the

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alkaline magma, it is seen at once to consist in the presence of potassium, which is wanting in the normal ferro-magnesian magma. Another characteristic is the prevalence of free quartz. Let it be supposed that the crenitic operation began to act on a doleryte, which Hunt supposes was probably the original rock, it may be asked, how could there be leeched out of doleryte a large amount of potash? It may also be asked how, while the potash was being extracted, and also the necessary amounts of lime, sodium and of aluminum, there could be obtained from the same rock an excess of silica which would give rise to a large amount of free quartz in the resulting product. If it be said that under exceptional conditions such a result might be produced locally, it is not sufficient, for exceptional and local conditions are not those demanded by the hypothesis. The extraction of the characteristic elements of the acid-alkaline magma from the ferro-magnesian is to be considered the usual and normal operation, for there is no reason in assigning the origin of one of the greatest rock masses of the globe to the operation of abnormal and exceptional conditions. It may be confidently asserted that no potash could be obtained from a rock or from a magma in which none existed, and therefore that the chief characteristic of the alkaline magma must have had some extraneous origin.

It is not to be inferred from this that Hunt overlooked the necessity of accounting for the origin of the alkaline silicates. It is necessary, therefore, to look a little more closely into his facts and his inferences from them. This, however, may be confined to his discussion of the secondary origin of orthoclase in connection with the diabase rocks of the Keweenawan, as in this mineral are contained all the elements of the investigation. It is plain that if orthoclase is found as a secondary mineral, as a result of change in a diabase, even in small amount, it is presumptive evidence of the extraction of potash from the associated diabase.

It is true that, prior to Hunt's announcement of the crenitic hypothesis, it had been shown by J. D. Whitney that orthoclase occurs in veins and sometimes in vesicular cavities in the trap rocks of the Keweenawan,* and this had also

*Am. Jour. Sci., (2), XXVIII, 16, 1859.

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been confirmed by Pumpelly in a masterly research into the metasomatic generation of various minerals of the copper-bearing rocks.* Hunt makes much of this fact, and expands it into such scope that he deduces the general law that the alkaline silicates are naturally one of the products of the crenitic process, and inferentially that the orthoclase of the veins and amygdaloids is a product of alteration of the diabase which contains them. This, however, is wholly a gratuitous and even impossible inference, not only because of the difficulties already referred to, but because of the attendant statements of Pumpelly. It will be seen, by an examination of the tabular grouping of the secondary minerals of the copper-bearing rocks presented by Pumpelly, that these minerals appeared in a certain order, as they are often super-posed in geodes and veins upon each other, and that orthoclase appears near the end of the series. In this table there are thirteen steps of mineral genesis, metallic copper being number six in the series and orthoclase number twelve. It seems, therefore, that not only did the zeolitic minerals all precede the formation of orthoclase, but also that metallic copper was earlier than orthoclase. The significance of the occurrence of orthoclase in cavities in the diabase, so far as that fact bears on the source of its elements, is less than that of the occurrence of copper, but if, for the sake of the argument, it be considered equal to that of the occurrence of copper, we are confronted, on the argument of Hunt, not only with the derivation of potassium from diabase, but also with the generation of metallic copper in large amounts from the same rock, neither of which elements exist in diabase in its normal and pure state.

We are, however, relieved of this difficulty by a different explanation. The origin of metallic copper in the Keweenawan rocks is now generally attributed to the circulation of mineral waters carrying the salts of copper in solution at a date considerably later than the origin of the diabase, such waters having parted with their copper occasionally in cavities in the diabase, but most abundantly in the cavities in the interbedded conglomerates†

*Am. Jour. Sci., Vol. II, Sep., Oct., Nov., 1871. Proc. Am. Acad. Arts & Sci., XIII, p. 253, 1878.

†Pumpelly, Am. Jour. Sci., Vol. II., 3rd Ser., p. 352, 1871.

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Such waters having an extraneous source their mineral character must also have had a foreign origin. They could not at least have been derived from the diabase, since the chief deposits are not in the diabase rock, but in a coarse conglomerate—and if from the diabase, on this evidence, then in much greater quantity from the acid conglomerate.

Therefore, if mineral solution from a foreign source deposited metallic copper at the sixth stage of the process, how much more likely that orthoclase, at the twelfth stage, was also generated by mineral solutions from an extraneous source, neither of these substances being indigenous in diabase.

It may still be claimed that all, or at least many, chemical analyses of diabase show the presence of a small amount of potassium which may have been sufficient at least to generate the orthoclase seen in the veins and geodes. Suppose that be admitted, it still demonstrates nothing. Such potassium found in diabase, or even in a soda-lime feldspar, is always accompanied by a certain percentage of water, as testified by chemical analyses, and the presence of water points to a certain amount of decay and the introduction of foreign ingredients. Theoretically there is no hygroscopic water, and no potassium in any of the minerals of a pure diabase. If water, potassium and metallic copper be found, on analysis, to exist in a certain diabase, they may all be considered equally as of later introduction from a foreign source, and they, therefore, could have had no agency in the supposed widespread transformation of the ferro-magnesian magma to an alkaline one.

Hence the principal evidence of Hunt for the leeching of potash by any sort of "fermentation," such as assumed by the crenitic hypothesis, and the generation of orthoclase, and hence of all the alkaline silicates, from a ferro-magnesian magma, seems to be inadmissible. If the principal step in support of the crenitic hypothesis is found to be unwarranted, all the subordinate and secondary steps in that process are rendered insecure and purposeless.

This difficulty also stands obviously against all other hypothetical processes of derivation of the alkaline-acid magma from the ferro-magnesian, whether by differentiation at the surface or in deep reservoirs, and the idea of such origin of

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the granite magma has to be abandoned, at least if any hypothesis more reasonable can be substituted.

The only other existing hypothesis for the origin of granite and the associated igneous rocks is that which refers them to the fusion of deeply buried sedimentary materials. This hypothesis, which at first glance seems to have a facies of reason and probability, is essentially that which was proposed by Hutton as contrasted with the oceanic view of Werner. With some modifications in the methods of application and operation this view has survived till the present. It was repeated by Keferstein (Naturgeschichte, des Erdkörpers, vol. I, p. 109, 1834); also Bull. Soc. Geol. France (1), vol. VII, p. 197); by Herschell (Proc. Geol. Soc. London, II, 548, 1836); Hunt (Geol. Magazine, June, 1869; Chem. Geol. Essays, 1874, p. 59), afterwards abandoned for the crenitic hypothesis); Le Conte (Am. Jour. Sci., Nov. and Dec., 1872); King (U. S. Geol. Ex. 40th Parrallel, vol. I, p. 705 et seq., 1878); Dutton (Geology of the High Plateaus of Utah, pp. 123 et seq., 1880); and the writer in 1888 (Am. Assoc. Adv. Sci. XXXVII, 212, 1888).

There are still more recent discussions of the manner and the physical conditions under which sedimentary rocks become plastic and flow as a molten magma, or crystallize in situ. Messrs. Crosby and Fuller (Mass. Inst. Tech. Quart., IX, 326-356, 1896; Am. Geol. XIX, 148, 1897) in discussing the origin of pegmatyte reach the conclusion that it is an intermediate representative between rocks deposited by solution and those that result from cooling, from fusion, that on one hand pegmatyte is inseperable from veins, which are of aqueous origin, and on the other grades into true granite which constitutes true dikes and bosses of igneous origin. They argue, therefore, for the intimate co-operation of heat and water not only in the formation of pegmatyte but of all granites. Through pegmatyte, therefore, there is a crystallline connection, open to observation, between the fragmental end of rock genesis and the igneous. The significance of this connection, in its bearing on the origin of granite, is not fully entered upon by Crosby and Fuller.

About the same date Prof. C. R. Van Hise has, in a masterful manner, gone into the principles of pressure, strain and

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plasticity which must apply to the deeply buried sediments (Sixteenth Annual Report of the U. S. Geological Survey, 1897), and shows that by the co-operation of aqueous and igneous agencies, simultaneously under great pressure, all rocks would be compelled to act in some measure the same as molten masses. Notwithstanding these suggestive links of connection between the igneous rocks and the clastics which they penetrate, Van Hise does not propose, any more than Crosby and Fuller, that there is any genetic bond between the clastics and the granites.

Although on several occasions there have been published in the reports of the Minnesota survey certain evidences of the transition of clastic rocks into crystalline rocks, such as gneiss, and granite-gneiss and finally into granite, there has not been until lately any careful investigation of the rocks themselves in their transitional petrographic characters.

But one locality has been studied in this manner. The field observations need not be rehearsed, for the megascopic facts are published in detail in the reports of the survey. This locality is that about Kekequabic lake. Here is a granite that shows both the clastic and igneous characters, as examined in the field. It is crystalline, massive and intrusive on the adjoining sediments, but grades off into fragmental rock, the gradation into fragmental rock being especially evident when the clastic rock was conglomeratic, the boulder forms of the coarse clastic still remaining.

Without going any more fully into the field evidence, it will be interesting, perhaps, to note the petrographic transition. This area of granite is small, a circumstance that brings the whole series involved between the granite and the fragmentals within narrow limits and warrants greater confidence in drawing the important conclusion. It rises in the form of a small dome in the middle of the Lower Keewatin. The clastic strata adjacent consist of siliceous actinolitic schist, in general terms, but they vary in different ways. The hornblende element becomes coarser, and the rock assumes the character of a peculiar porphyry. At other times the hornblende is partly replaced by augite which is allied to ægyrine, and in nearly all cases it can be seen to have been derived from augite by a uralitic alteration. This derivation is evinced chief-

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ly by the parti-colored polarization which sometimes represents exactly the original crystal form of the idiomorphic augite, surrounded by fringes of external growth beyond the augite limits. When the augite grains were fragmentary, or were corroded before being enclosed in this rock, the hornblendic growths have exactly filled them out, the dark color of the polarization (or even the color seen in ordinary light) showing distinctly the original augite outlines. Besides the conspicuous hornblendes sometimes this schist contains traces of feldspars, but usually feldspar is not evident except when the whole rock becomes coarser. When feldspar is seen distinctly in the schist, the crystals often appear to have been altered into a micro-granulitic mass of secondary grains which appear to be of quartz and feldspar. Sometimes pellet-like spots appear, under the microscope, which are occupied by such granulation. By their assuming distinctly lighter and darker aspects four times in one revolution, there appears to be a remnant of the original feldspar grain with its orientation still intact. The "ground mass," so to speak, surrounding these altered crystals, is composed largely of finer condition of the same elements, but usually it embraces also a notable amount of quartz, which is in the form either of free grains of angular clastic shapes or of fine and intimately interlocked chemical deposition. With the fine-grained quartz is apparently also equally fine feldspar.

This green schist is sometimes composed almost wholly of actinolite spicules. At other places it passes into a greenish graywacke. It is distinctly a fragmental rock, and shows a coarse, even pebbly structure, the pebbles being usually of rock like itself, but finer-grained. It is considered to be largely of the nature of an old volcanic tuff, grading, as it does, into the greenstones of the Keewatin.

In the first place it should be noted that there is a striking mineralogical affinity between the schist-conglomerate and the crystalline rock, in that they both contain augite, and that this augite is of the nature of ægyrine; also that the feldspars of the schist-conglomerate, having very striking and unusual characters, are duplicated in the granites—i. e., the original feldspars are remarkably twinned and zoned. This statement as to the augite is not demonstrated, but rests on the concur-

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rent evidence of other microscopic character. It is evident that in such a schist it would be almost impossible to find augite retaining its crystalline form, for it readily changes to hornblende, that being indeed almost the first mineralogic change that takes place in a volcanic tuff of such age. But the augite cores remain in the schist, sometimes, as augite, and, on a still broader scale, the original forms of the augites are outlined in the resultant hornblendes by difference of absorption and of colors between crossed nicols. Exactly the same characters are seen in the augites of the porphyry and granite-porphyry, where the preservation is sufficiently perfect to disclose the ægyrine characters of the original augite. As to the sameness of the feldspars, with their peculiarities, there is no question.

These two important characters ally these rocks in some way in a genetic bond, for the feldspars especially are wholly unlike any known elsewhere in the state. Chemical analysis points to anorthoclase, but the zoned structure, when analyzed by the microscope, indicates that the feldspars began as labradorite, passed to andesine, and, sometimes at least, terminated as albite, there being a continual increase in the acidity of the magma in which they were generated.

The general aspect of the granite (seen in thin section) along the south side of Kekequabic lake is suggestive, not of crystallization from a magma, but of simple induration of coarse debris. The feldspar grains do not interlock, except as they have been enlarged by a secondary growth, and in many sections examined they do not even come into contact, but are separated, very generally, by a space which is occupied by a fine interlocked secondary development of feldspar and quartz. The margins of the feldspars frequently are interlocked in this new growth. *As this fine matrix increases in amount, so the rock becomes porphyritic; as it increases in coarseness, so the rock becomes granitic*, but in all cases, or in nearly all, there is a distinct difference between the old feldspars and the new. Along with this generation of new feldspathic material, is also the recrystallization of the quartz, thus making a truly granitic rock. The old feldspars, which in the schists proper, without metamorphosis have a tendency to disappear by a process of micro-granulitization into a fine

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mesh of secondary feldspar and quartz resembling the surrounding matrix, are by metamorphism regenerated by new borders, and by micro-granitic growths of coarser grain, and by these new growths interlock about their margins. Occasionally the old feldspars embrace and surround idiomorphic small crystals of augite, having taken that relation in the magma in which they were generated, but the later feldspars do not enclose augite in that way. When the fragmental augites are not altered to hornblende, which alteration is usual, they are simply embraced between the newly developed feldspars. The old feldspars, thus contrasted with the new, can be distinguished with more or less certainty in nearly every section examined.

Again, in the midst of the sedimentary schist are found coarser, hardened beds that present as compact and crystalline a texture as some of the intrusive granite. Such recrystallized beds are associated conformably with others that are not so hardened, the regular sedimentary relation and structure being continuous through them all. This hardening and recrystallization of the schist evidently is irregular in distribution. Throughout the schist, even in its least metamorphic conditions, there is a fine background of micro-granulitic quartz, or quartz and feldspar, which is ready, in case of the application of new forces, to take on new forms. The background matrix, in the porphyry as in the granite, is the same, fine interlocked quartz, or quartz and feldspar. In the porphyry it seems to be a micro-granulitized feldspathic debris, for numerous feldspars can be seen, partially changed to such a micro-granulitized condition.

It is, however, with the conglomeratic condition of the sedimentaries that the most evident transitions occur to the granite. These are conspicuous in the field, and with the microscope the finer elements are seen to be simply compacted together with but slight interstitial material. The crystals all being, as supposed, of the nature of volcanic ejecta arranged somewhat by water, the elements of the rock embrace these with small amounts of erosion products, the latter increasing with distance from the supposed volcanic source. One of the most evident and instructive instances of granitized conglomerate is that seen along the south shore of the lake

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in sec. 31, T. 65-6. The fragmental character is most evident, and many of the pebbles are rounded. There is no short transition, but the whole rock over a certain belt acquires the granitic texture by the secondary development of interlocking minerals. The original, clastic, feldspars were mainly in fragments, but some were nearly complete as crystals. They are cemented together by fresh feldspars and by quartz. As grains they never interlock with one another.

The facts, taken ensemble, seem to warrant the conclusion that the same rock is both clastic and intrusive, and therefore that as an intrusive it is derived from the clastic beds in situ, and had no deep seated source. This is not an isolated case of the observed recrystallization and intrusive action of clastic strata. In the Adirondacks, according to numerous observers, the limestones have been made to intrude the adjoining quartzytes and gneisses, and to surround isolated portions of them much in the same manner as igneous rocks. This fact led Emmons and some of the early geologists to class crystalline limestone amongst the igneous rocks.

If this source of the granitic rocks be admitted in the case of the Kekequabic lake granite, it is likely to have been equally efficient in other localities, and, indeed, it rises to the importance of a general cause applicable, in the absence of other sufficient source, to all the granites of the state.

It remains only to call attention to one of the consequences of this hypothesis, should it be accepted. It is necessary to find in the clastics which accumulated between the epoch of the basal greenstones and the intrusion of the granites, the excess of silica and the potash which characterize the alkaline magma. That the schists and sedimentary gneisses contain a large amount of free silica, and also much orthoclase and microcline, is a fact which only needs to be mentioned to be admitted by every petrographer. In case those rocks suffer refusion it is inevitable that the rock produced would contain the same elements.

We know of no way, other than erosion and volcanic action, and the chemical precipitations provoked by such action, by which the sedimentary products of the Archean could have accumulated. As erosion of the ferro-magnesian rocks that seem to have constituted the first crust could not, as already

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shown, have given rise to these chemical peculiarities, they must have come from the waters themselves, and primarily from the sky, either as volcanic tuffs or as precipitations from the surrounding atmosphere. It is reasonable to presume that the early volcanic products would be like the early crust, ferro-magnesian, and not alkaline. We are to look for these elements, then, rather to the atmosphere in its normal condition—i. e., in its condition normal to the Archean age, just following the congealing of the first crust. The question is then one that is chemical and physical, and is resolved into an inquiry whether the world's great stock of potassium was stored up in the Archean because of the operation of the Laplacean hypothesis in its progressive unfolding. It is a question which leads into an examination of the volatile point of potassium and into its chemical properties and its probable activities under Archean conditions, and as such it is beyond the scope of this paper.

GLACIAL THEORIES—COSMICAL AND TERRESTRIAL.

By E. W. Claypole, Pasadena, Cal.

The enigma of the Ice age is still unread. When the general scepticism which greeted the promulgation of the doctrine had given place to acceptance the cause of so portentous an interruption of geological evolution became a topic for investigation of the first importance. And it has proved to be a topic of extreme difficulty. While it is now impossible to deny the occurrence of glacial conditions, probably several times repeated during the recent history of the earth, yet it has thus far been impossible to discover any sufficient or satisfactory cause for so great and widespread a lowering of the temperature over much of the temperate zones—a lowering that was sufficient to bring Arctic conditions almost down to the latitude of 35° in North America, and to 45° in Europe, to cover the mountainous regions of the globe everywhere with thick sheets of snow and ice and to extend the antarctic cold to limits only a little less wide than those over which the northern glacial winter prevailed.

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The early speculation of Lyell in the later editions of his classic works were marked by the caution so characteristic of the man. Attempting to find in changed relations of the land and water a sufficient cause for extensive changes in the temperature, and at the same time lacking the necessary data in soundings and in geological observations outside of Europe he could do little more than theorize. And as the progress of discovery showed that little solid basis exists at present or had existed in time geologically recent for many of his speculative changes, the terrestrial theory, as it may be called, gradually lost ground. It seemed impossible by means of admissible recent geographical movements to find any sufficient cause for so vast a refrigeration as that which the observed phenomena of the Ice age appeared to require. Geologists began to look elsewhere and to seek in extraterrestrial of cosmical conditions a solution of the mystery. Variation of the sun's heat from age to age was assigned as a possible means of accounting for contemporaneous variation of the temperature of the earth. But no proof or even probability of any such change could be produced. The variability of variable stars is in all likelihood due to totally different causes. Inequality in the temperature of the regions of space through which our system is careering is another altogether gratuitous assumption on which a glacial theory has been founded. But it is as baseless and as contrary to probability as the former. Moreover, as it has been more than once pointed out, either of these two theories would have cut off the glaciers at their source by reducing the evaporation and consequently the rainfall.

The only cosmical theory that has been rendered sufficiently plausible to command acceptance is that which was put forward more than a quarter of a century ago in the pages of the "London, Edinburg and Dublin Philosophical Magazine" by Dr. James Croll. This, which was in effect terrestrial, though based on astronomical facts was supported by its author with such ability and ingenuity that it obtained for a time very general approval in the geological world. It not only assigned a possible and seemingly a probable cause for the oncoming of the Ice age, but required its recurrence at least several times during the past, and its repetition on a smaller scale during

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each recurrence. Moreover, it offered so tempting a means of linking together geological and astronomical times that it awakened a hope that the two might ere long by its agency be united. The fundamental fact also—the secular elongation of the major axis of the earth's orbit—was so firmly established that it admitted no dispute, and the secondary principles deduced from it were invested by the skill and eloquence of the author with such a halo of efficiency and probability that no one need feel any surprise at the rapid advance of the theory in the geological world.

But with the progress of research there have "cropped out" certain difficulties and objections which were but slightly, if at all, conspicuous at the outset. Among these is the condition demanded by Dr. Croll's theory that the arctic and antarctic eras of glaciation were not contemporaneous but alternate. With this it stands or falls. But geologists can find no evidence for the alternation. On the contrary all the facts bearing on the question, though few, fail to show any difference in date. The ice-marks, whether scratches, grooves, or boulders, are equally fresh in both hemispheres, so that it is impossible to believe in a difference of 20,000 years in their age as required by the theory. Then the work done on the surface since the ice passed away is too little to fill the long interval of 80,000 years which Dr. Croll assigns to the past glacial era. The gorges of Niagara and of St. Anthony are too small to have supplied occupation for their streams during so long a time. Many other similar facts point very strongly in the same direction, so that geologists generally are more disposed to bring the close of the cold era and the disappearance of the ice within ten or fifteen thousand years than to admit the 80,000 years of the Croll hypothesis. Again, the apparent irregularity and want of contemporaneity shown by the glacial phenomena in various places indicate a less general cause than one whose action extended at once over a half of the globe.

These and other considerations have during the past few years gradually undermined the hypothesis of the brilliant Scotch geologist, so that it may now be said to stand much less securely than it did twenty years ago. In spite of its accounting for the recurrence of glacial and interglacial condi-

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tions as no other has ever done, there is yet a consciousness that its base is slipping away and that the superstructure is unstable.

As a result attention has been again directed to strictly terrestrial conditions, and the newest results of investigation have been employed in order to find, if possible, sufficient cause for so intense a period of refrigeration in latitudes so low. The contour lines of the Atlantic have been quoted to prove that ancient continental shores exist at two levels, which have been named respectively the "Continental" and the "Blake" plateaux. To bring both these above the sea-level at present would need an elevation of ten or twelve thousand feet to the south and much less to the north. So great a change of level, if real, must have been attended with momentous results, both in the drainage and the temperature, and the investigation of these details is the most recent line of research in glacial geology. Beyond all question it is quite possible to picture a state of things much resembling the Ice age with the data thus supplied. The diversion of the gulf stream or its reduction in temperature would certainly chill the north Atlantic and the British Isles and might even so far reduce the temperature as to cause a precipitation in the winter which the summer might be unable to melt, thus producing an actual Ice age. Add the refrigeration due to the postulated elevation of the temperate coast of the north Atlantic to that due to diversion of the warm current, and the two may well be allowed to have produced more momentous climatic changes, perhaps even all the phenomena of the Ice age in western Europe and eastern North America.

The importance of this contribution to the literature of the subject can scarcely be over-estimated. It suggests a possible cause for at least a part of this mysterious episode in the history of our earth. But it is very far from completeness and equally far from meeting all the conditions of the problem. We may fully admit that vast elevations and depressions of parts of the surface have taken place without being compelled to admit the elevation of the West Indies to the extent of 12,000 feet. But to deny its possibility would be equally illogical. There are numerous side-issues needing consideration and many minor problems awaiting solution be-

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fore the elevation in question of the "Continental" and the "Blake" plateaux can be accepted as the cause of the Ice age. Some of them may be worth stating.

1st. An elevation of 12,000 feet over any large area is known only in Thibet, where the great Desert of Gobi or Shamo constitutes the wildest, windiest and snowiest region outside of the arctic circle.

2d. Assuming as a fair rate of elevation three feet in a century we should require 400,000 years for the uplifting of the "Blake" plateaux above the Atlantic level, so that the time since the Ice age reached its maximum would on this theory exceed even the long limit assigned by Croll.

3d. In order to allow the occurrence of interglacial periods we must assume not a continuous but an intermittent elevation with alternations of subsidence, allowing amelioration of the climate. Moreover, if the elevation was the main cause of the refrigeration these subsidences must have ensued to an extent sufficient to cause this amelioration. We shall therefore be compelled to postulate in this case not one, but several oscillations, almost or altogether to the full extent given above, a result which will multiply the length of the glacial period several times and render the discord still greater than in the case of the theory of Croll.

4th. It will be necessary to find similar conditions in other regions in order to explain their glaciation. Not the basin of the north Atlantic alone but almost every other part of the temperate zones and even the mountainous regions within the tropics have been witnesses of a great extension of their present glacial systems. It is not easy to require elevation over all these places at once or even consecutively. Nor is it any easier to conceive how the results of elevation elsewhere could extend over districts so remote. The diversion of the gulf stream by the Antillean uplift might chill the north Atlantic but could scarcely affect the Kiwu Siwu of the Pacific or change the climate of Patagonia or of New Zealand. If the crust of the earth has been so uplifted and depressed in all these regions as to cause the Ice age the Pliocene and Pleistocene eras must have been a time of instability exceeding what now comes within geological experience.*

*Note: See for further details on this subject a paper by the writer on "Eccentricity versus the Facts" in the Trans. of the Edinburgh Geological Society for 1891, and also "Glacial Notes from the Planet Mars" in the American Geologist for 1895. Vol. 16, p. 91.

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It would not be just to infer that in consequence of these objections the "elevation-theory," as it may be called, is not a valuable contribution to glacial literature. On the contrary every possible solution of even a part of the greatest problem in Pleistocene geology is welcome. Even if it prove incapable of solving the whole it may yet be an important aid to the attainment of the desired results. Probably the publication of Dr. Croll's hypothesis even if it should prove, as now seems likely, entirely incompetent, has done more to stimulate the progress of glacial geology than any other single event of this century.

It is scarcely necessary to add that any theory of the Ice age must be capable of explaining all the many and intricate facts connected with it and must, of course, be in accord with the actual course of recent geological history. At the same time the full investigation of all the physico-geological ramifications of any fundamental first cause of the Ice age must be a task of excessive intricacy and length. Consequences may come to light apparently quite unrelated to it which are yet its necessary though distant results, and it is not improbable that this strange chapter in the history of the earth may at last be found to be an outcome of more than one principal cause whose interaction has brought about the remarkable consequence—a singular point in a curve—an intersection of two mathematical lines—a physical result exalted by accidental coincidence with another.

INTRAFORMATIONAL CONGLOMERATES IN THE GALENA SERIES.

By F. W. Sardeson, University of Minnesota.

(Plate IX.)

The continuation of the Trenton and Hudson River groups, as they are most often designated, from New York state westward through and beyond the Ohio river basin, is well known to geologists and a description here of their extent

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is doubtless unnecessary. This paper has to do with the equivalent or continuation of the Trenton group in the upper Mississippi basin, especially at St. Paul, Minnesota. To explain briefly: the Chazy formation, the Trenton including the Black River formation and the Hudson formation including the Utica of New York are, as is generally recognized, represented in this area by three divisions, the St. Peter sandstone, the Galena series and the Maquoketa series respectively. It is still somewhat indeterminate whether the Trenton stage comprising the formations or divisions just mentioned, has all its subdivisions represented in the upper Mississippi basin. The Trenton stage is very thick in the New York region while the equivalent here is thin, not exceeding 400 feet. Yet a complete sequence of beds would appear to be developed in both regions and the much thinner western representative is probably not to be considered as an incomplete one, but rather each subdivision there may have its coordinate here. This hypothesis accords further with the great uniformity and wide extent of each bed of this stage in the Northwest. In a former article.* I have endeavored to show how the several parts of the Galena and the Maquoketa series are nearly coextensive over their known extent, but I was not able to describe an exact relation between the Trenton stage of New York and that of the Northwest, because the necessary store of evidence for such an undertaking is not at hand. A few data only were contributed on the deposits here. Ruedemann,† White‡ and Prosser and Cumings§ have materially increased our knowledge of the New York Trenton stage deposits in recent articles.

Ruedemann describes especially evidences of oceanic currents in the Utica formation and again similar evidence from conglomerates in the Trenton formation. Although it may be very little known to geologists, yet conglomeratic zones exist in the Galena (Trenton) series in Minnesota and Wisconsin, and evidence of marine erosion or corrosion recurs in it at several horizons. These zones, moreover, appear to mark the divisions between successive faunal and stratigraphic beds.

*American Geologist, vol. 18, p. 357; vol. 19, p. 21.

†American Geologist, vol. 21, p. 75; vol. 19, p. 367.

‡Trans. N. Y. Acad. Sci., vol. 15, p. 71.

§Fifteenth Ann. Rep. N. Y. State Geologist, p. 619.

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and may be found in fresh strata both in the limestones and the shales or clays. Possibly the newly discovered conglomerates in the New York area may be genetically correlative with some of those in the Northwest.

At Saint Paul and Minneapolis, Minnesota, quarries have been opened revealing unweathered strata in the Galena series, and in these may be observed the exact demarcations between beds and strata. There are the first six beds of the series in place here (see plate) and a large part of the Saint Peter sandstone exposed below them. The tops of the several beds carry either a conglomerate or again a corroded surface merely, while the bases of the same bear no similar structure. A contrast may be drawn therefore between these and basal conglomerates; these being evidently due to corrosion mainly, are of small mass and lie at the top of the stratigraphic subdivisions, within the formation, while the others are due to erosion and form a large mass lying at the formation's base.

Beginning with the oldest Galena stage stratum, i. e., from the top of the Saint Peter sandstone there is found at Minneapolis, and similarly at Saint Paul, an abrupt transition from the pure sand to a mixed sand and clay deposit two to three feet thick upon which is a stratum of clay and calcium carbonate containing a few fossil imprints. This stratum is two feet or less thick. The next stratum, which is less than two feet thick, may be designated a limestone. It is compact, but contains numerous smooth, black-surfaced, irregular pebbles which contrast strongly with the blue or buff color of this and other strata. A few inches from the top of the stratum is a black seam or surface and the rock is discolored to a slight depth. The surface is somewhat polished although it is not uniformly plane. Above it the rest of the stratum, four to six inches thick, is irregularly shaly and bears patches of numerous small black pebbles and coarse quartz grains, associated with or in large fucoidal casts, which may have been algæ. I interpret the characters of these strata as indicating that the top of the Saint Peter sandstone was disturbed and its sand mixed with clay deposited at the time which the first succeeding stratum represents. The next stratum indicates quiet undisturbed sedimentation. The next one, which contains the black seam or smooth surfaced lamina, shows that a con-

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siderably thicker deposit first accumulated, but was largely reabsorbed during an interval of non-deposition. The reabsorption left the surface irregular and the top of the stratum saturated with oxide of iron and manganese. Extreme irregularities of the surface may have given origin to loose isolated blackened pebbles, or the same may be parts of a broken up stratum or lamina, reduced by absorption like the ground surface. The existence of these pebbles through the stratum above and beneath the black seam indicates that more than once such periods as the blackened surface represents, had obtained, but that the result of their existence, the black surfaces had been later broken up. The association of fucoids with the pebbles may indicate that the latter were sometimes transported by the former, which their proportionate size would seemingly also indicate.

The above described strata lie at the base of the Buff limestone bed at the bottom of the series, (see plate IX). This bed is about thirteen feet thick excluding the transition strata just described. The top of the Buff limstone bed has also a black stained irregular semi-polished surface, upon which the first laminæ of the succeeding bed, the Bellerophon bed, rest in a sort of non-conformity on a small scale. The limestone strata part along this plane and its existence is often obscured by weathering, but again in many places one can observe well how the upper limestone penetrates the small irregularities and borings in the blackened surface of the lower one. Again the Bellerophon bed has the upper surface of its top stratum irregularly sculptured and blackened. Here there is often a discontinuous lamina with its surface also blackened and bored. resting upon the main surface. The first succeeding stratum, belonging to the Stictoporella bed, is usually limestone but a shaly carbonaceous thin layer here and there intervenes.

Black pebbles, such as are abundant near the first, or lowest corrosion zone are not observed with the second and third. But the fourth one which is in the top of the Stictoporella bed (plate IX) has on the contrary pebbles, and not a continuous blackened surface associated, at that place. In the topmost laminæ of this bed, among numerous fossils, are flat irregularly moulded pebbles about one inch in width and smaller. The Stictoporella bed is mainly composed of clay

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shale in its upper portion and in this the pebbles are embedded, or again they are in the shaly surface lamina of a limestone stratum. It seems remarkable that the pebbles lie in the top of the Stictoporella bed and not in the basal portion of the succeeding one. Their position is like that of the pebbles and the blackened irregular surfaces at the top of lower lying beds.

The fourth of the series of beds has also its conglomerate in the highest layers. The bed is 30 or more feet thick. It is composed of clay with more or less discontinuous layers of limestone one to three or four inches thick. At Saint Paul this bed has been excavated recently in such a manner as to permit the unweathered undisturbed strata to be closely studied. About ten feet below the top there is a thick lamina of oolitic limonite. The same is not preserved in the weathered clay and for that reason probably it has never before been observed. Pebbles a foot wide and three or four inches thick and smaller ones occur two feet below the oolyte lamina and again near the top of the bed. These strange occurrences have been found distributed or partly heaped together in a manner to show that they form a conglomerate. They are parts of broken up limestone strata and both their composition and content of fossils show them to have been broken from the bed in which they now lie. The pebbles are irregularly lenticular, smooth or bored full of holes, blackened and partly encrusted by Bryozoa, monticuliporoid corals, crinoid roots, etc. They rest sometimes obliquely upon one another like shingle. They are mostly large pieces, several inches wide and are embedded in fine, fossil-bearing clay or in fossiliferous limestone strata which are not unlike that from which the conglomerate pebbles must seemingly have been derived. To explain this intraformational conglomerate it seems not necessary to assume that the pebbles as such are the result of erosion, but rather that the exposed top of the bed being a limestone stratum, which was not covered by other deposit, it was attacked by the sea water and reduced to lenticular pieces. Their blackened, bored and encrusted surfaces show that they lay a long time upon the sea bottom. But they are alike on both sides, and again they seem to represent more than one stratum and it may therefore be necessary

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to further assume that water currents were strong enough to disturb them at least by moving the clay from around them, and to bury them again. The limestone stratum from which they came had consolidated before they were formed. The sedimentation was interrupted in the same manner two or more times during the deposition of the upper third of the bed.

Following the Stictopora bed comes the twenty foot thick Fucoid bed, which is the fifth in the series. The bed is a clay with calcareous laminæ and fucoids interspersed and a few firm limestone strata intervening. At or near the top there is again oolitic limonite to be found and close below it a few cake shaped pebbles two to six inches wide. The top stratum is an impure but brittle limestone. Its upper surface when exposed shows a blackened planed field, with numerous abrupt pits and borings characteristic, one might say, of a sea bottom. But it is not encrusted by Bryozoa or other fossils. The stratum itself bears no well preserved fossils and seemingly none of any kind except fucoids, but these nearly compose all the upper strata, and are abundant throughout this bed. Succeeding strata are very fossiliferous and minute shells and zoaria are often beautifully preserved in large numbers. They belong to the Orthisina bed. About nine feet above the Fucoid bed the strata contains pebbles similar to those in the Stictopora bed, although smaller and more dispersed. They lie in the lower half of the Orthisina bed, but at the top of a division which I here formerly designated as the Zygospira bed.

It is evident to one examining the Galena series' strata that the six beds exposed at Saint Paul and Minneapolis are separated by intervals of non-deposition of sediments. The beds are characterized by faunal differences and the interruptions in the life sequence now appear to coincide with interruptions in deposition of sediment. Of course the deposition of sediment may have ceased innumerable times during the building of the several beds and not infrequently etched shells and zoaria bear evidence that they lay long unburied on the sea's bottom, but intervals sufficiently long to permit marine erosion and corrosion to form blackened unconformable surfaces and black manganese stained pebbles, mark the upper parts of the

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beds as described. The seeming exception in the lower part of the first bed or Buff limestone may rather be in accord with the rule and the strata between the corrosion zone and the Saint Peter sandstone should accordingly be designated a distinct bed. Heretofore this part has been called the "transition" although the paucity of fossils and its rare exposures have left us in doubt whether or not it is a distinct faunal zone. Recent investigation of it has resulted in the finding of several species all but one of which occur in the overlying bed; the one species however is quite strange and has not yet been identified. It is an *Ophileta*. In the Stictopora bed the last twelve feet of the 30 or 35 feet bear first a conglomerate, then an oolyte zone and possibly other lesser conglomerate zones besides the chief one at its top. This part of the Stictopora bed seems the most irregular in thickness of any part of the series, although one can not be certain of that because its position in the middle of the shales causes it to be seldom well exposed. An attempt to delimit it faunally, following the suggestion of E. O. Ulrich has not resulted successfully except in so far as it has been proved that Rhynchonella ainsliei N. H. W. recurs in this part of the Stictopora bed, and that it is the zone of the rare *Leptæna halli* Sar. It is highly fossiliferous. In general it bears the same relation to this bed as the few inches of conglomeratic shales at the top of the Stictoporella bed do to that one (see plate IX). The conglomerate zone in the Orthisina bed which is nearer the bottom than the top, lies however at the top of a faunal zone, which might be designated by a separate name but which could not however be distinguished in other places, because of imperfect preservation.

The rule is then without exception here that the sedimentary small non-conformities coincide with faunal changes and these both may be assumed to have a common cause, namely, intervals of no sedimentation in their time. This relationship may be useful as an aid to correlation of the related formations.

At Saint Paul and Minneapolis the strata are well preserved and when they are exposed by quarrying the described phenomena can be well observed. None of the rocks, as a rule, are altered to a vesicular texture as in the Galena series

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elsewhere and it should not be expected therefore that the phenomena, which are clearly shown here, will be found as well displayed in other places even though the conglomerates had been widely distributed. In a few instances, however, such phenomena are described from other places, and quite probably they are not uncommon.

Prof. T. C. Chamberlin described one of these erosion or corrosion zones which is seen at Platteville in southwestern Wisconsin. He writes "The upper surface of the typical glass rock near Platteville, shows a smooth eroded upper surface with an occasional fracture of the upper layer through which the subsequent deposit penetrated."* This occurrence has been seen by me recently, and it is found to be at the top of the Stictoporella bed and thus corresponds to the fourth corrosion zone at Minneapolis and Saint Paul. I have already described the Orthisina bed conglomerate from Kenyon, Minnesota (op. cit. p. 29), which is like that at Saint Paul. Also the oolitic or semioolitic deposits which have been seen from Saint Paul for 100 miles southeastward at various exposures have been before mentioned (op. cit. p. 28). These occurrences with possibly many others which have not yet been noted may prove the wide continuation of the several corrosion zones in the lower and middle Galena (Trenton) series.

The remaining beds of the series, numbers 7, 8 and 9, forming the typical limestone called Galena limestone in geological reports is altered to a vesicular structure with many concretions in nearly all known exposures, and it will not therefore be readily determinable whether the recurring corrosion zones continue upwards into these beds. Such may have existed similarly or on even smaller scale than in the lower beds. Here and there they might be discoverable in well preserved strata. Very often in fact the rough faced strata of the dolomytes and the irregular compressed or reduced shale laminæ, simulate the corrosion zones. But, again concretionary structures and limestone nodules from the disintegration of shaly limestones might be mistaken for the conglomerate above described when percolating water had removed the black stain of their surfaces. Therefore it can not be assumed that corrosion zones exist where they have

*Geol. Wis. vol. 4, p. 413 and fig. 8.

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not been observed in good preservation. The observed relation of the corrosion zones with the upper limits of the stratigraphic and faunal divisions or beds lends however an additional significance to these in the upper parts of the series and wherever they occur although unaccompanied by corrosion or erosion phenomena.

EDITORIAL COMMENT.

Drygalski's Glacial Studies in Greenland.

The Geographical Society of Berlin has published the report of its scientific expeditions to Greenland, which were under the direction of Dr. Erich von Drygalski, in 1891, and again leaving Copenhagen on May 1, 1892, and returning October 14, 1893. The work is in two volumes (pages 556 and 571, with 53 plates, 10 maps, and 85 illustrations in the text; Berlin, W. H. Kühl, 1897). Studies of the inland ice-sheet by Drygalski were the chief purpose of these expeditions, the district selected for special examination being that adjoining the Umanak fjord.

Much attention is given in this report to the questions of the probable configuration of the interior of Greenland, under its thick ice-sheet, and of the physical conditions of outflow of the ice. The processes of glacial erosion, transportation, and deposition of the drift are very instructively described and discussed; and the author's general conclusions are well summarized by Prof. James Geikie in a review given in Nature (vol. 58, pp. 413-416, Sept. 1, 1898), as follows:

> With regard to the ground-moraine itself, there can be no question that this is partly carried in the lower portions of the ice, and partly pushed forward underneath, and, further, that the forward movement must result in the deformation of underlying unconsolidated formations. The moving force is, of course, in the ice itself. With the augmentation of included débris the mobility of the mass is impaired, internal friction increasing the more closely the materials are crowded together. It is only when débris is well saturated that under pressure movements like those of the ice itself can take place. In a compact subglacial mass of débris the movement communicated by the flowing ice above must,

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owing to friction, quickly die out downwards. Only a relatively thin layer of ground-moraine, therefore, can travel onwards underneath the ice. Immense quantities of material, however, are interstratified with the lower layers of the "inland ice," and these are eventually added to the ground-moraine. The amount of this included or intraglacial débris depends upon the thickness of the ice, and must thus vary from place to place. As the ice diminishes in thickness, its ability to transport rock-materials declines, and the rubbish begins to be deposited below. Dr. Drygalski thinks that the boulder-clays of North Germany were in all probability deposited in this way. Thus wide sheets of boulder-clay and the "end-moraines" of a great ice-sheet have had the same origin—they consist of ground-moraine accumulated under the thinner peripheral portions of the ice.

Drygalski's view closely coincides with the opinions which the present writer has stated in several papers, that the drift was chiefly transported englacially, in the lower part of the ice-sheet, and that it was probably thence deposited in large measure subglacially near the borders of the receding ice, while another large part became superglacial and was allowed to drop loosely on the surface. From these thorough studies of the Greenland ice-sheet, with the equally elaborate and valuable observations of it, as bearing on the origin of our Pleistocene glacial drift, by Chamberlin and Salisbury much farther north, and with Russell's exploration of the partly drift-covered and forest-clad Malaspina glacier in Alaska, we obtain much aid toward a comprehension of the conditions which attended the retreat of the great American and European ice-sheets. But we have yet much to learn, and the numerous expeditions now being made in both Arctic and Antarctic regions will doubtless still further extend and broaden our knowledge derived from present ice-sheets as illustrating the Glacial period. W. U.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

[*New York*] *Fifteenth Annual Report of the State Geologist* [Prof. JAMES HALL] *for the Year 1895. Volume I.* Pages 738, with many plates, maps, and sections; Albany, 1897.

Among the many reports that have been published by our state and national geological surveys, this stands first, or at least in the front rank,

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as to the quality of its typography and illustrations, and the sumptuously wide margins of its pages, which make it an exceptionally ponderous volume. From the standpoint of a librarian, who must adjust his shelves according to the size of his books, a smaller quarto or octavo form would be more satisfactory.

The administrative report, with synopses of the work of assistants in the field and office, relating to the geological map of the state, occupies 20 pages. In this part the reader finds the outlines of the results that are more fully stated by these assistants in the fourteen papers which constitute the remainder of the volume, as follows: The Stratigraphic and Faunal Relations of the Oneonta sandstones and shales, the Ithaca and Portage Groups in central New York, by John M. Clarke (pp. 27-81, with 7 plates of scenery, 2 geological maps, and 9 figures in the text); The Classification and Distribution of the Hamilton and Chemung series of central and eastern New York, Part I, by Charles S. Prosser (pp. 83-222, with 13 plates of scenery, a large geological map, and many sections in the text); The Stratigraphic Position of the Portage sandstones in the Naples valley and the adjoining region, by D. Dana Luther (pp. 223-236, with two plates, a map, and a section); The Economic Geology of Onondaga county, New York, by D. Dana Luther (pp. 237-303, with 21 plates, 2 maps, and 12 figures); The Structural and Economic Geology of Erie county, by Irving P. Bishop (pp. 305-392, with 16 plates, and 6 maps); Geology of Orange county, by Heinrich Ries (pp. 393-475, with 44 plates, including many maps and sections); Report on the Crystalline Rocks of St. Lawrence county, by Charles H. Smith, Jr. (pp. 477-497); Report on the Geology of Clinton county, by Henry P. Cushing (pp. 499-573, with 5 plates, a county map, and geological maps of the separate townships); Preliminary Report on the Geology of Essex county, by James F. Kemp (pp. 575-614, with 12 plates, including a county map and large geological maps of several townships); Sections and Thickness of the Lower Silurian formations on West Canada creek and in the Mohawk valley, by Charles S. Prosser and Edgar R. Cumings (pp. 615-659, with 12 plates of scenery, and 3 figures of sections in the text); Report on the Talc Industry of St. Lawrence county, by Charles H. Smyth, Jr. (pp. 661-671); Physical tests of the Devonian shales of New York state to determine their value for the Manufacture of Clay Products, by Heinrich Ries (pp. 673-698); The Discovery of a Sessile Conularia, by R. Ruedemann (pp. 699-728, with 4 plates, being in large part the same as his articles, with plates, in the American Geologist for March and April, 1896); and Notes on some Crustaceans from the Chemung group of New York, by John M. Clarke (pp. 729-738, with four figures in the text). A large geological map of Albany county, on the scale of a mile to an inch, by N. H. Darton, is inserted at the end of this volume.

Professor Hall's work for this state survey during more than sixty years, with that of his associates and assistants, long ago made New York the leader and exemplar of all other surveys on our continent in relation to the stratigraphy, paleontology, and correlation of the Paleozoic formations; and this work was continued with unabated industry and

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efficiency to the end of his life, as attested by this annual report. The second volume, which is yet to be issued, will comprise Hall's discussion of Streptelasma and allied genera of rugose corals, and his memoir on the Paleozoic hexactinellid sponges constituting the family Dictyospongidæ. More than 120 species of this family, in 29 genera, are known and will be described, with illustrations, in this memoir, more than 70 of these species being recognized in the Chemung fauna. W. U.

Interglacial Deposits in Iowa: a Symposium presented at the Iowa Academy of Sciences, Des Moines, Dec. 28, 1897. Papers by SAMUEL CALVIN, FRANK LEVERETT, H. FOSTER BAIN, and J. A. UDDEN; 41 pages, with plates IV-VII, and two maps, reprinted from the Proceedings of the Academy, vol. V, 1898.

Abstracts of the papers comprised in this brochure were given in the American Geologist for April, 1898 (Vol. XXI, pp. 251-264). Nearly all of our American glacial and interglacial formations, so far as they have been already somewhat fully discriminated, have a good development within the state of Iowa; and several members of that series, as the Aftonian, Buchanan, and Iowan, are there most typically developed, and thence derive their names. The rapidity with which these formations have been discriminated and first published under these names during the last four years, and the important changes of their order required by the study of sections in Iowa, make it very desirable to consider them in their sequence and relationships, as in these papers. According to the nomenclature proposed in successive parts by Chamberlin, G. M. Dawson, Calvin and Leverett, the series is as follows, in the order of age from the earliest to the latest: 1. Albertan till; 2. Aftonian interglacial deposits, probably equivalent with the Saskatchewan beds; 3. Kansan till; 4. Buchanan interglacial beds, with the Yarmouth zone of weathering and erosion; 5. Illinoian till; 6. Sangamon interglacial deposits and weathered zone; 7. Iowan till; 8. Peorian soil and associated modified drift, including the chief mass of the loess, especially prolonged in its deposition adjacent to the Altamont moraine in northwestern Iowa; 9. Early Wisconsin moraines and till; 10. Later Wisconsin moraines and till. Through this classification, with names of geographic origin, the Mississippi and Saskatchewan basins become the standard of comparison for future studies and correlation of the North American stages of the Glacial period, like the New York nomenclature for the periods of the Paleozoic era. W. U.

Report on a Traverse of the Northern Part of the Labrador Peninsula from Richmond Gulf to Ungava Bay. By A. P. LOW. Geol. Survey of Canada, Annual Report, vol. IX, Part L, 43 pages, with four plates; Ottawa, 1898.

The journey of exploration here reported was made during the summer of 1896. It included about 500 miles of travel by canoes and over portages, the route being up the Wiachouan and Clearwater rivers to Clearwater lake; thence north to Seal lake, tributary to Hudson bay by the Nastapoka river; and thence by the Stillwater

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and other rivers of the Koksoak system to Fort Chimo. Thence the party sailed in the Hudson Bay Company's steamer to Rigolet in eastern Labrador, and from there to Quebec in a schooner.

Laurentian granite and gneiss occupy the greater part of the area traversed; but Cambrian strata, dolomyte, sandstone, and chert, border the east side of Hudson bay at Richmond gulf, and other Cambrian beds are found in parts of the Koksoak basin, including probably workable deposits of magnetite and hematite.

Glacial drift, in greater or less amount, overspreads all the country. In the interor it often consists largely of pregiacially decayed rock-material, apparently not far displaced by the ice movement; and many of its boulders there are probably residual masses from such subaërial weathering and erosion. On the low grounds the till is usually amassed in drumlins, trending approximately in parallelism with the outward glaciation of the peninsula. Eskers are frequent, having similar courses and running along the valleys, as in New England.

Thirty-five terraces or beaches, of marine formation during the Champlain epoch, the highest being 460 feet above the sea, were crossed on the portage leaving Richmond gulf; and higher terraces, regarded as probably also marine, occur up to an altitude of 710 feet. On the descent to Ungava bay the highest marine terraces noted are about 620 feet above the sea level.

In Seal lake, fifty miles long and from half a mile to five miles wide, nearly 800 feet above the sea and about a hundred miles distant from it, either the common harbor seal (Phoca vitulina) or a closely allied species, lives and breeds in considerable numbers, thirty or more being killed annually by the Indians. The seals are thought to have come into this lake during the Champlain submergence, which must have nearly or quite connected it with Hudson bay, "and having found it full of fish they probably lost the inclination to return to the sea." This explanation, which is doubtless true, appeals to a simple and somewhat uniform epeirogenic uplift, less complex and less prolonged, we may believe, than the earth movements which will be found to account for the seals and many species of marine crustaceans in the great Siberian lake Baikal, about 1,500 feet above the sea and having a maximum sounding of 4,746 feet. In both these instances the connection with the sea was geologically recent, in contrast with the probably remote time when lake Tanganyika, 2,680 feet above the sea, and of undetermined depth exceeding 1,200 feet, received its jelly-fish and numerous species of mollusks, prawns, and protozoa, of marine derivation. Orogenic as well as epeirogenic movements, with profound crustal deformation, quite certainly shared in separating the basins of these greater fresh-water lakes from the ocean, giving to them a far more complicated history than that of Seal lake, which merely participated with all the Labrador peninsula in the general uplift from the Late Glacial or Champlain depression.

W. U.

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Text-book of mineralogy, with an extended treatisee on crystallography and physical mineralogy. EDWARD SALISBURY DANA. New edition, entirely re-written and enlarged, with nearly 1000 figures and a colored plate. 8vo, viii + 593 pages, $4.00, John Wiley and Sons, New York: 1898

This work takes the place, in most elementary and classroom work, of the "System of Mineralogy," by Dana, of which it is, in its descriptive portion, an abridgment. Its physical and chemical portions, especially that relating to optical methods, are more full than the same in the larger book, so that by this text book the modern student may be made acquainted with nearly all the methods of mineralogical investigation. It is to be commended for its adoption of the Miller system of symbols, and for the use of symmetry as a basis of classifying all crystal forms, making thirty-two groups. N. H. W.

Manual of Determinative Mineralogy, with an introduction on Blowpipe Analysis. GEORGE J. BRUSH. Revised and enlarged, with entirely new tables for the identification of minerals, by SAMUEL L. PENFIELD. 8vo, pp. x + 312, 15th edition. John Wiley and Sons, New York: 1898.

This excellent work is still further improved by the addition of an entirely new chapter, devoted to the physical properties of minerals, especially crystallography. The remainder of the introductory portion is essentially the same as in the last (14th) edition, but the tables which have been for a long time familiar to the American student, are amplified and altered so as to cover nearly 800 species, and the new facts of mineralogy, their general scope and plan being the same as before. The work therefore is no longer a treatise on blowpipe manipulation and determination, but becomes a general manual for the determination of minerals by all methods excepting the study of their optical characters. N. H. W.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Adams, Geo. L.

The Upper Cretaceous of Kansas. (Univ. Geol. Sur. Kans., vol. 4 Paleontology, Part 1, pp. 13-27, 4 pls., 1898 [with addenda by S. W. Williston]).

Ashley, Geo. H.

Note on fault-structure in Indiana. (Proc. Ind. Acad. Sci., 1897, pp. 244-250, 2 pls. [1898]).

*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

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Bailey, L. W.

Report on the Geology of Southwest Nova Scotia, embracing the counties of Queens, Shelburne, Yarmouth, Digby and a part of Annapolis. (Geol. Sur. Can., Ann. Rept., vol. 9, 1898, 1 map, 5 pls).

Bain, H. F. (and A. G. Leonard.)

The Middle Coal Measures of the western interior coal fields. (Jour. Geol., Sept.-Oct., 1898, vol. 6, pp. 577-588).

Ball, T. H.

The Cady Marsh. (Proc. Ind. Acad. Sci., 1897, pp. 240-242 [1898]).

Bell, Robt.

Report on the Geology of the French River sheet, Ontario. (Geol. Sur. Can. Ann. Rept., vol. 9 ,May 3, 1897 [1898], 1 map).

Bennett, L. F.

Four comparative cross-sections of the knobstone group of Indiana. (Proc. Ind. Acad. Sci., 1897, pp. 258-262, plate of sections [1898]).

Blake, Wm. P.

Bison latifrons and Bos arizonica. (Am. Geol., vol. 22, Oct., 1898, p. 247.)

Bownocker, J. A.

The paleontology and stratigraphy of the Corniferous rocks of Ohio. (Bull. Sci. Lab., Denison Univ., vol. 9, May, 1898, pp. 12-40, 1 pl).

Bryson, John.

Drift formations of Long Island. (Am. Geol., vol. 22, Oct., 1898, pp. 245-247).

Case, E. C.

The development and geological relations of the vertebrates, part 3. Reptilia [Studies for Students]. Jour. Geol., Sept.-Oct., 1898, vol. 6, pp. 622-646).

Chamberlin, T. C.

A systematic source of evolution of provincial faunas. (Jour. Geol. Sept.-Oct., 1898, vol. 6, pp. 597-608).

Chamberlin, T. C.

The influence of great epochs of limestone formation upon the constitution of the atmosphere. (Jour. Geol., Sept.-Oct. 1898, vol. 6, pp. 609-621).

Clark, W. B.

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CORRESPONDENCE.

GLACIAL OBSERVATIONS IN THE CHAMPLAIN-ST. LAWRENCE VALLEY. Two points of considerable interest came under my observation during a recent excursion in Canada.

1st. *A Buried Channel in the Valley of the Maskinonge River.*—This stream enters into lake St. Peter from the north, about seventy miles below Montreal. The line of hills which forms the border of the old Laurentian continent, is about fifteen miles back, and forms a well-defined line visible from the river through the entire distance. A well-defined terrace, rising about fifty feet from the river, is encountered about two miles inland. From this point on to the Laurentian hills there is a gradual rise over an even surface of boulder clay until an elevation of something over two hundred feet is reached at the base of the hills. This glacial deposit is deeply eroded.

Where the river breaks through the Laurentian barrier it descends by a waterfall nearly two hundred feet high, and finds its way into a preglacial valley running at right angles to the fall, the river itself having turned abruptly to enter the gorge. This preglacial gorge was found to extend about a mile northward with very little glacial debris filling it. At this point, however, it was entirely filled with glacial debris, which forms a complete obstruction. For several miles above as far as to Rousseau Platte the stream is very sluggish, while the banks and the bottom are of sand and clay. But so extensive are the deposits of modified drift that it was impossible to tell just where the buried channel was or how far up it extended. The whole condition of things, however, furnished a striking and fresh illustration of the now well-established law that in the glaciated region a waterfall is sure indication of a buried channel in the near vicinity. Indeed it was not difficult to recognize in the gentle inclinations of the sides of this preglacial valley the enormous lengths of time during which preglacial rivers had been doing their work, nor in the small amount of erosion at the present site of the waterfall, the very limited time during which the stream had occupied its present channel. For the privilege of making these observations I am indebted to the kindly interest of Messrs. Frank Wing and C. H. Simpson, of New York city, who have summer residences in that region.

2nd. *Lateral Moraines near Plattsburgh, N. Y.*—Mr. S. Prentiss Baldwin in his paper in the American Geologist (vol. xiii., p. 181), alludes to a possible terminal moraine in Altona township, Clinton county, N. Y., about ten miles northeast of Plattsburgh. Here there are three or four well-defined parallel lines of morainic deposits just above the level of the highest terrace of the Champlain epoch, which is here about four hundred feet above the sea. I had the privilege of being conducted over the region by Dr. D. S. Kellogg and Prof. Hudson, of the Normal school. Our observations led us to conclude that these deposits could more properly be called lateral than terminal mo-

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raines; while one of the ridges seemed to us like a much-prolonged drumlin such as those that characterize central New York. The direction of the ridges of till is northeast and southwest, corresponding both to the direction of the scratches upon the rocks and of the strike of the strata of Potsdam sandstone forming Rand hill, which rises to a considerable hight to the west. The facts as we saw them were of special interest from their bearing upon the discussion of Prof. Spencer's paper at the American Association meeting in Boston in which he maintained that it was necessary to suppose a subsidence of fifteen hundred or two thousand feet to account for the horizontal terraces found at the various elevations upon the flanks of both the Green and the Adirondack mountains. But these lateral moraines in Altona indicate the true explanation.

It seems evident that in the decline of the glacial period the ablation of the ice from the surface in this region led at a certain period to the appearance of the tops of these mountains as lines of nunataks, while the Champlain valley was still full of ice. As the ablation proceeded, the effect of these lines of nunataks on either side was to keep the margins of the ice lower than the middle. This would naturally result from their influence in absorbing and reflecting the heat. From this resulted a gradual working of the glacial debris toward the margin, where it was variously modified by the streams of water which were running between the sides of the ice and the mountains, much as is illustrated in one of Prof. Russell's photographs from the Malaspina glacier. In this way these high-level horizontal terraces in Vermont, described by Prof. Spencer, would be formed without the extensive subsidence which he supposes. And Mr. Baldwin is doubtless correct in believing that Baron De Geer has, on account of the same mistake, placed the extent of the subsidence at St. Albans, Vt., at two hundred feet more than it really was. Mr. Baldwin's account, on page 176 of the paper already referred to, of the typical moraine terrace 560 feet above the sea at Crown Point, appears to be a striking confirmation of this interpretation of the facts.

It may be well to note, in this connection, that the discovery by professors Hitchcock and Richardson of Canadian boulders near the summits of the Green mountains, and far up upon the flanks of the Adirondacks, would seem to settle the question which has been in dispute between some of the Canadian geologists and those upon this side of the line respecting the actual invasion of the Champlain valley by Canadian ice.

G. FREDERICK WRIGHT.

Oberlin, Sept. 23, 1898.

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ON THE DIKES IN THE VICINITY OF PORTLAND, MAINE.

By E. C. E. LORD, Washington, D. C.

(Plate X.)

Along the coast of Maine trap dikes are very abundant. In his "Geology of Northern New England," professor Hitchcock mentions the following localities: Mount Desert, Marshall, Little Deer Island, Vinal Haven, Hancock, Ellsworth, Bluehill, Brookville, Rockland, Thomaston, Hope, Whitehead island, Windham, Limerick, Gorham, Casco bay and Portland.

Professor G. P. Merrill in describing the Maine building stones* refers at length to diabase from Addison Pt., Indian river and Vinal Haven. Other localities from which similar rock has received detailed study are: St. George†, Seward's island in Frenchman's bay,‡ Kennebunkport,§ Lewiston and Auburn ¦ and the Fox islands.¶

The region to be described in this paper embraces a part

*Proceedings of the United States National Museum, Vol. VI., No. 12, 1883.

†Q. E. Dickerman and M. E. Wadsworth: On Olivine Bearing Diabase from St. George, Me. Proc. Boston Soc. Nat. Hist., Vol. XXIII., p. 28.

‡W. O. Corsby: Geology of Frenchman's Bay, Me. Proc. Bost. Soc. Nat. Hist., 1880, p. 109.

§J. E. Kemp: On the Dikes near Kennebunkport, Me. Amer. Geol., Vol. V., 1890, p. 129.

¦ George P. Merrill: On Some Eruptive Rocks in the Vicinity of Lewiston and Auburn, Androscoggin Co., Me. Amer. Geol., Vol. X., 1892.

¶ G. O. Smith: The Geology of the Fox Islands, Me. Dissert. Inaug. Johns Hopkins University, 1896.

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of the Casco bay, and the southern portion of the Freeport quadrangle of the United States Geological Survey.

The fjord-like character of the bay with excessively indented coast-line, and the effects of glaciation on the islands are well brought out on the map.

The trend of the islands is northeast, and corresponds with the strike of the crystalline schists composing them. These schists are, according to Hitchcock,* of Huronian age, and extend from near Saco river to Harpswell, abutting against gneiss (Laurentian) on the east, and are overlain to the west and northwest by strata of Cambrian age.† They consist of finely stratified micaceous quartzytes, biotite, chlorite, and actinolite schists, merging locally into garnetiferous and staurolitic varieties. These strata are undoubtedly of clastic origin, but their original structure is in many cases almost totally destroyed by the far reaching effects of a regional metamorphism. They have a remarkably regular N. 50°—60° E. strike, and are generally inclined at high angles to the north or south. Cleavage is especially well developed in the fine grained micaceous schists forming the greater part of the series. On weathered surfaces this rock bears frequently quite a striking resemblance to irregularities of surface of decaying, coarse-grained timber, and breaks up locally in long thin layers, not unlike fence rails. A slab, showing this peculiar form of weathering, is figured in "Rocks, Rock-weathering and Soils," by Prof. G. P. Merrill, MacMillan & Company, 1897. In describing it (page 248) the author says:

"The finely fissile schists, standing nearly on edge along the coast of Casco bay, in Maine, under the combined influence of wave and atmospheric action, weather into peculiar fantastic forms resembling nothing more than piles of lumber in which multitudinous channels formed by boring coleopterous larvæ have become irregularly enlarged by decay."

Apart from secondary folding and some local shearing and faulting the schists show evidence of considerable jointing subsequent to the intrusion of the dikes. The jointing affects the

*Chas. H. Hitchcock: The Geology of Portland, Me. Proc. Amer. Assoc. Adv. Sci., Vol. XXII., 1884, p. 164.

†See geological map of Maine. C. H. Hitchcock: Geology of Northern New England, 1885, p. 5.

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schists and dikes alike, and consists of two systems of vertical fractures intersecting each other at an angle of about 30°, and causes the rock to break down in rhomboidal blocks when exposed to the direct action of the waves. The schists are overlain at various points by glacial deposits, and frequently along the shore considerable stretches of beach sand are met with. This sand is ordinarily of the common white variety, consisting principally of quartz with some feldspar fragments and flakes of mica, but occasionally it is colored brownish red, owing to local accumulation of rounded garnet crystals.

The glacial deposits are especially well developed at Portland and a point on cape Elizabeth, about two miles south of the city. They consist of basal, or lower boulder clay, composed chiefly of large, highly striated rock-fragments, and of an upper, looser, brownish-red till, which at Portland merges at the top into gravel beds.

This glacial debris has been removed to a great extent from the islands in the bay, especially from those immediately facing the ocean. Even great Chebeag island, having a somewhat protected position, is but lightly covered with gravel and boulders.

The low, flat islands of the inner bay (Mackey, Clapboard and Basket islands) are composed of reassorted glacial material similar to that forming the marine terrace which fringes the adjoining coast.

The study of the basic dikes about Portland was taken up to discover what relations, if any, exist between them and the diabasic intrusions of Kennebunkport and Bald Cliff, and, if possible, to ascertain the nature of the parental mass from which they originated. The prosecution of the work developed many features of special petrographical interest.*

These basic dikes occur on the islands of Casco bay, and the eastern shore of cape Elizabeth, and can be followed as far south as Prout's neck, some three miles beyond the limit

*The work was carried on in the petrographical laboratory of the U. S. National Museum in Washington, D. C., and the writer wishes to acknowledge his thanks for facilities offered, and the privilege of studying the collections. He is especially indebted to professor G. P. Merrill, head curator, Dept. of Geology, in the museum, for many valuable suggestions, and to Dr. Thomas L. Watson for advice and aid.

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of the area studied. They form a very conspicuous feature of the coast, partly on account of their dark color, which generally stands out in strong contrast to the lighter gray tints of the schists, but especially owing to the fact that they weather out more rapidly than the surrounding rock, leaving straight channels with vertical walls to mark their original location.

They belong, with a single exception, to one general series with a very persistent N. 55° E. strike, and essentially vertical dip. This conformity in strike with that of the schists is indicated on the map. These dikes rarely exceed six feet in thickness, and are usually from only two to four, but they frequently can be traced for considerable distances along the coast; thus No. 14, at Broad cove, cape Elizabeth, possessing peculiar mineralogical characteristics, is easily recognized again on Bailey's island, a distance across the bay of nearly fourteen miles.

The exception referred to is a dike 80 feet thick, of a coarse grained enstatite-diabase-porphyry, occurring on the eastern side of Cousin's island, and extending across the southern end of Littlejohn's island in a general easterly direction.

The prevailing character of these intrusions is dense porphyritic, with occasional coarser crystalline varieties, depending upon the physical conditions under which the rock-magma solidified. The walls of the dikes in direct contact with the schists are aphanitic, and in some cases almost vitreous, whereas in the central portions, especially of the larger dikes, a coarser texture prevails. Even granular varieties are not frequent. (7, 10, 17, 24, 26.)

The mineral composition of the rock in general is that of *olivine-diabase-porphyry*, consisting of olivine, augite, plagioclase and magnetite. Subordinate types, containing as diagnostic constituents enstatite or hornblende, will be classed as *enstatite-diabase-porphyry* and *camptonyte* respectively.

Previously to the intrusion of the diabase and camptonyte occurred that of *granitic* rock. A large *pegmatyte* dike (32) with aplitic extensions (31) forms a part of the western shore of Biber's island, and can be followed in a northeasterly direction through Pettingill's, Williams' and Sister island to Mare

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point on the mainland. The walls of this dike have been rendered in places quite schistose by extensive lateral pressure. The rock is very coarse grained and shows macroscopically a beautiful graphic intergrowth of quartz and feldspar. On microscopical examination this feldspar is seen to be microcline, penetrated by irregular lamellæ of albite. Besides quartz and this microcline (perthite) the rock contains some muscovite, and a few grains of accessory apatite.

The *aplyte* is a white, even granular rock with peculiar saccaroidal texture, and consists mineralogically of microcline, orthoclase, albite, muscovite, garnet and apatite. The garnet is in the form of very regular octahedra of a light pinkish color.

Examples of *olivine-diabase-porphyry* are from dike 1, 2, 3, 4, 5, 6, 7, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 29, 30.

The specimens vary in color from steel gray to bluish black. On exposed surfaces they weather brown. The habit of the rock is in general basaltic with phenocrysts of olivine, feldspar, augite, magnetite and irregularly shapped masses of pyrite. With the aid of the microscope, the ground mass resolves into a panidiomorphic aggregate of augite, lath-shaped plagioclase, magnetite and apatite. It is in every instance holocrystalline, although frequently the rock itself appears on exposed surfaces to be scoriaceous, owing to cavities having been formed by the decomposition and leaching out of the olivine phenocrysts.

The *olivine* is exclusively of intratelluric origin, and, when well preserved, the characteristic planes 100, 110, 021 could be easily identified. (7, 10, 21, 22, 24, 26.) Frequently, however, products of decomposition obliterate the crystal form, leaving in place of the crystal a fibrous aggregate of sepentine, accompanied in many cases by calcite and epidote. The amount of olivine varies considerably in the different specimens.

The *augite* is the most important mineral constituent of these rocks. The crystals are either prismatic in form with octagonal cross-sections, owing to equal development of 110, with 010 and 100, or they are somewhat tabular formed by the pinacoid 010. Twinning after this face is not uncommon.

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The crystals vary in color from purplish brown to light yellowish green; the former being the most common, and decidedly pleochroitic: purplish brown parallel to **a** and **b**, pale yellow parallel to **c**. Absorption is strong:-**a** > **b** > **c**.

These crystals are rarely homogeneous; they have usually the well-known hour-glass structure in which the lighter colored inner part of the crystal, with the optical properties of diopside, is surrounded by a purplish rim of titaniferous augite resembling optically the ægyrine-augite of Rosenbusch. On sections parallel to the plane of symmetry this outer rim shows a very strong dispersion of the bisectrices (the angle c: **c** *s* > c: **c** *v*) and a large angle of extinction (the angle c : **c** = 57°) against only 51 degrees, measured in the same way, for the inner portion.

The pale yellowish green variety of augite is confined apparently to dikes of somewhat andesitic character (3, 5, 6, 10, 12, 13, 15, 16, 17, 18, 19, 21, 25), containing an abundance of plagioclase with but comparatively little olivine.

This pyroxene is optically identical with the diopside center of the titaniferous augite.

The augite breaks down readily into chlorite and limonite (6, 10, 14, 15, 16, 18, 20, 21), and in some instances it is replaced by a yellowish brown mica (12, 17, 25), with strong pleochroism:—brownish yellow parallel to 001, pale yellow perpendicular to 001.

The formation of this secondary biotite proceeds usually from the exterior inwardly along the prismatic cleavage cracks of the pyroxene—as is clearly demonstrated in dike 12—but occasionally it is confined to the central portion of the crystal only, leaving the outer part perfectly fresh (12).

The *plagioclase* varies but little in form, and in optical properties—the phenocrysts being stout, tabular, formed after 010 in the coarser grained rock, and thin lath-shaped in the groundmass and in denser varieties. The crystals are frequently polysynthetically twinned in accordance with the albite law, and have on 010 sections an average extinction angle of 20 degrees, which, with a specific gravity of 2.70, would place them in the group of normal labradorites ($ab_3 an_4$). In a few coarse grained dikes of camptonitic character (1, 2, 20, 25, 30), the feldspar has a smaller angle of extinction, approximating that of anorthoclase.

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Under normal conditions the labradorite is, excepting the olivine, the first constituent to undergo decomposition. In one dike, however (14), it was found remarkably fresh, while the augite and olivine were completely decomposed. The alteration products are kaolin, calcite, and in one instance, chlorite (18).

Magnetite in the form of well developed octahedra, or as a delicate net-work of skeleton crystals (13) is very abundant. In some rock specimens this mineral is altered to leucoxene.

Apatite is of normal prismatic development, and quite plentiful in most slides.

The even granular dikes (7, 10, 17, 24, 26) differ solely in structure from the porphyritic varieties. The mineral development is, with the exception 10 and 24, panidiomorphic, like the ground mass of the diabase porphyry. In 10 and 24, the augite occurs partly as interstitial filling, thus giving the specimens a somewhat ophitic structure.

Enstatite-diabase-porphyry (27, 28) is a coarse grained porphyritic rock differing from the olivine-diabase-porphyry chiefly in the preponderance of pyroxene over other constituents, and by the occurrence of enstatite in place of olivine. The augite of this rock is pale green resembling very closely the diopside of the andesitic types of diabase-porphyry. (See page 340.)

The crystals of *enstatite* are of beautiful prismatic development, and have the weak double refraction common to this mineral. They vary in length from 1 to 4 mm, and are nearly quadratic in cross-sections, owing to the predominance of 010 and 100 over the prism 110, which truncates the edges of the crystals. Cleavage parallel 110 and 010, and parting planes approximately normal to the prism axis are common features of this mineral. Along these planes chloritization is in many cases far advanced (27).

The chemical composition of this rock (28) is given under I, and for comparison that of augite-porphyryte is reproduced from professor Kemp's paper.*

	I.	II.
SiO_2	50.76	51.93
Al_2O_3	12.83	18.13

*Op. cit., p. 138.

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Fe_2O_3	4.98	8.92
FeO	10.09	
MgO	6.67	5.30
CaO	9.88	9.82
Na_2O	3.52	4.34
K_2O	.62	1.42
H_2O	.87	.69
	100.22	100.75

The chemical similarity of these rock-types is apparent. The augite-porphyryte, or diabase-porphyry as it has been called in this paper, is somewhat richer in alkalies and alumina, and poorer in iron and magnesia than the enstatite-diabase-porphyry, which can be explained by considering the fact that the latter rock contains relatively less feldspar, and more ferromagnesian constituents than the angite-porphyryte.

Camptonyte is represented by dike 8 and 9. This rock has formed the topic of considerable discussion since it was first described by Hawes* under the name of dioryte. The broader significance of the term as applied by Rosenbusch† has been modified by American authors—notably Kemp and Marsters‡—to embrace only such varieties of diabasic dike-rock in which hornblende predominates. An appreciable amount of augite gives rise to an intermediate type—augite-camptonyte.§

Adopting this latter classification we have but one dike of true camptonyte (8), No. 9 being augite-camptonyte. The camptonyte dike (8) occurs at Portland head-light on the east coast of cape Elizabeth, cropping out again on the western shore just beyond the map border. It is about six feet thick, stands almost vertical and has the prevailing N. 55° E. strike of the adjoining dikes.

*G. W. Hawes: On a Group of Dissimilar Eruptive Rocks at Campton, N. H. Am. Jour. Sci., Ser. III., Vol. XVII., p. 14.

†H. Rosenbusch: Massige Gesteine, 3te Auflage, pp. 535-550. Stuttgart, 1896.

‡J. F. Kemp and V. F. Marsters: The Trap Dikes of the Lake Champlain Region. Bull. 107. U. S. Geolog. Survey, p. 30.

§For literature on camptonyte see V. F. Marsters: Camptonite and Other Intrusives of Lake Memphremagog. Amer. Geologist, Vol. 16, 1895. Page 35-36.

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The rock is of a bluish-black color and porphyritic structure containing some phenocrysts of serpentinized olivine, besides a small scattering of purplish brown augite, magnetite and pyrite.

The ground mass consists of idiomorphic brown hornblende, anorthoclase, magnetite and the decomposition products, chlorite and calcite.

The *hornblende* crystals are of prismatic development, rarely exceeding 1 mm in length. They have strong pleochroism in brown and yellow tones ($c > b > a$), and the small angle of extinction common to barkevicyte — the angle $c : c = 11$ degrees in maximo.

These minute amphibole needles contain in some instances the remnants of partially resorbed augite with similar crystallographic orientation—thus clearly demonstrating them to be, in part at least, of paramorphic origin from the augite.

In order to compare the chemical composition of this barkevicitic hornblende with that from Barkevik, large phenocrysts were extracted from the camptonyte from Campton Falls, N. H.,* and analyzed (I). No. II is an analysis of barkevicite given by Brögger from augite-syenite near Barkevik (Skudesundsskjár).†

	I.	II.
SiO_2	37.80	42.46
TiO_2	4.54	
Al_2O_3	12.89	11.45
Fe_2O_3	6.14	6.18
FeO	12.55	19.93
MnO		0.75
CaO	13.64	10.24
MgO	4.10	1.11
Na_2O	5.26	6.08
K_2O	3.24	1.44
	100.16	99.64
	Spec. gr. 3.47	Spec. gr. 3.43

No. II is seen to contain 6.39 per cent. MgO+CaO and 1.80 per cent. K_2O less than No. I, but the main difference lies

*This material was obtained from a specimen of the original dioryte of Hawes in the collection of the U. S. National Museum.

†See P. Hintze: Handb. der Miner. Leipzig, 1893, p. 1257.

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in the iron (FeO) of which the hornblende from Barkevik has 7.38 per cent. more than the brown amphibole from Campton Falls, N. H.

The *anorthoclase* crystals are lath-shaped parallel to à, and show in places a tendency to radial arrangement. They are characterized optically by a small angle of extinction (the angle a : a=ca.10°), which renders them easily distinguishable from the labradorite of the diabase-porphyry. Polysynthetic twinning could not be identified,—the crystals being apparently single individuals.

The anorthoclase decomposes readily to calcite and kaolin.

An analysis of this feldspar (I) was made from dike 8. The material was completely separated by means of the Thoulet solution and afterwards exposed to a strong magnetic current whereby many fragments containing inclusions of hornblende or magnetite were removed. For comparison are given under II the analysis of anorthoclase from the "Rhombenporphyr" of the Christiania region (Tyveholmen)* and under III that of murchisonyte from an augite-syenite dike near Ula, between Sandfjord and Laurvik, South Norway.† No. IV is the analysis of the camptonyte (dike 8), and V and VI those of enstatite-diabase-porphyry and augite-porphyryte, already given on page 341.

	I.	II.	III.	IV.	V.	VI.
SiO_2	57.34	59.57	64.96	45.20	50.76	51.93
TiO_2				0.68		
Al_2O_3	20.79	22.69	19.32	17.12	12.83	18.13
Fe_2O_3	2.88	2.47	.89	5.98	4.98	8.92
FeO				6.55	10.09	
CaO	4.27	5.05	1.19	7.89	9.88	9.82
MgO	.16	.42		5.29	6.67	5.30
Na_2O	8.09	6.38	7.26	4.23	3.52	4.34
K_2O	4.17	2.50	5.84	2.31	.62	1.42
H_2O	2.66	1.34	0.29	5.35	.87	.69
	100.36	100.36	99.84	100.60	100.22	100.75

On glancing over the first three analyses it is apparent that No. 1, although about 3 per cent. richer in alkalies, and

*See Mugge: Jb. Min., 2, p. 107, 1881.

†W. C. Brögger: Mineralien der sudnorweg. Angit-syenite. Zeit. für Kryst. von P. Groth, Leipzig, 1890, Vol. 10, p. 546.

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containing nearly 2 per cent. less Al_2O_3, and SiO_2 than the anorthoclase from Tyveholmen (II), is much closer related to this variety of feldspar than to the murchisonite from Ula (III). It appears that the latter mineral, from its high percentage of SiO_2 (64.96) and K_2O (5.84) combined with but 1.19 per cent CaO, contains a larger amount of the orthoclase molecule than either of the other two.

The chemical relationship of the camptonyte (IV) to the augite-porphyryte from Kennebunkport (VI) is closer than that of the enstatite-diabase-porphyry (V) which occupies in a certain sense an intermediate position between these two, although containing more ferrous iron and magnesia.

From what has been said it appears that the basic dikes in the neighborhood of Portland vary in mineral composition from an enstatite-diabase-porphyry, containing enstatite, diopside, plagioclase and magnetite, to a camptonyte, composed of olivine, hornblende (barkevicite), anorthoclase, and accessory augite.

These basic intrusions are almost in a direct line of strike with those from Kennebunkport and Bald cliff, and as the main rock-types from the three areas are (with the single exception of the enstatite-diabase) essentially identical mineralogically and chemically, there seems scarcely any doubt of their genetic relationship.

The chemical affinity of the brown hornblende and anorthoclase of the camptonyte, with the barkevicite and soda-feldspar of augite-syenite from Norway has been pointed out (see pages 343-344), and it is therefore possible that some at least of the basic dikes from the Maine coast are offshoots from an underlying parental rock of this description. It is suggestive in this connection to note the occurrence of large inclusions of augite-syenite in a camptonyte dike from Kennebunkport.*

This syenite is of a pinkish gray color, somewhat mottled, owing to dark areas of magnetite and augite scattered through the flesh colored, granular feldspar. Originally the rock was composed of orthoclase, green augite (diopside) with some magnetite and apatite, but subsequent fusion and re-

*Probably dike 64 of Kemp. op. cit., p. 131.

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crystallization of the pyroxene and adjoining feldspar have caused some rather remarkable changes. The products of regeneration are confined to the dark areas, and consist of lath-shaped anorthoclase, purplish brown augite needles and beautifully developed magnetite octahedra, besides the corroded remnants of the diopside.

These newly formed minerals resemble very closely those of the camptonyte proper and frequently, on the contact, grade into them imperceptibly.

This rather unusual assimilation of a foreign inclusion by an intrusive magma, might perhaps speak for a chemical affinity between the two rocks.

Regarding the age of these intrusions little can be said with any degree of certainty. It would seem from general appearances in the field that the acid dikes are of greater age than the basic intrusions—as is the case at Kennebunkport. On the Fox islands, however, somewhat further north, Dr. Smith (op. cit. p. 64) has found this order to be reversed. Here the granitic dikes penetrate both diabase and diorite, and are clearly younger than the latter rocks. At some localities they are furthermore distinctly seen to be of more recent age than the quartzitic schists, and the overlying Niagara and pre-Niagara series.

The remarkable conformity in strike of the dikes in Casco bay with that of the enclosing schists renders it probable that they represent the products of volcanic energy, coincident with one of the great paleozoic movements of the Atlantic border region. It is conjectured that this movement occurred towards the close of the Devonian period, contemporaneously with the granitic intrusions of Nova Scotia, New Brunswick* and Vinal Haven,† but a careful geologic study of the entire Maine coast is necessary before this problem can be definitely solved.

*See J. W. Dawson: Quart. Journ. Geolog. Soc., Vol. 44, p. 814.
†G. O. Smith: op. cit., p. 75.

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[Contributions to the Mineralogy of Minnesota. II.]

THOMSONITE AND LINTONITE FROM THE NORTH SHORE OF LAKE SUPERIOR.

By N. H. WINCHELL, Minneapolis, Minn.

Thomsonite. The megascopic characters of this mineral, as already stated, are somewhat different from those of mesolite. It is not known to possess those peculiar cat's-eye markings; its fibres are coarse, and the cavities in which it is found are large and of irregular branching shapes, as compared with the round or oval masses of mesolite. It is white and divergently fibrous, and sometimes it is found in the same masses with mesolite, with which it is intimately interlocked. It seems to take some part in the recurring bands of color which constitute the marked characteristic of mesolite.

Its microscopic characters differ from those of mesolite not only in the manner already mentioned under mesolite, but in the spreading and ofter fern-like forms which the fibres assume, as they radiate and develop from a common point. This mineral is orthorhombic, and has strictly parallel extinction. Its optic plane is parallel to the base 001, and hence its fibres show sometimes a positive and sometimes a negative elongation. Its optic angle, which contains n_g, is small, and hence sections perpendicular to n_g are much darker than those perpendicular to n_p. The double refraction is strong (0.027, Lacroix).

It has already been stated that this zeolite is sometimes intimately mingled with mesolite. This but rarely occurs as straight, conspicuous, independent fibres of mesolite, piercing obliquely the thomsonite mass, but has been seen rather to consist in close, nearly parallel, minute fibres which appear at certain zones in the recurring colored bands of the mesolite. They are distinguished then by their greater light when they happen to present the axis n_p perpendicular. The axis n_g is so dark that it cannot be distinguished in the fine mesh, from the general mesolite mass, but those that happen to be cut perpendicular to n_p appear as bright, short needles, sharp at both ends, which are quite light compared with the rest of the section. This is seen in sections of the zeolites from Terrace point, (535 A).

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Localities of Thomsonite. Probably Isle Royale furnishes this mineral in greater amount than any equal area in Minnesota. It occurs at the Island Mine, at Chippewa Harbor, at Scovill's point and at two miles SW from Locke's point, on the north side of the island. On the north shore of the lake, in Minnesota, it has been detected at Terrace point (near Grand Marais), at Fall river where it can be seen to be a product of alteration of labradorite (200 A), at Poplar river and eastward, east of Pork bay (163 A) and at Beaver bay. At the last point it forms the chief constituent in veins in the anorthosyte masses at the west point of the bay. It occurs in the rock of Encampment island.

Lintonite. Associated with mesolite and thomsonite at Terrace point are occasional light green, apparently amorphous, small round pebbles, usually found in best form in the debris of the beach. These are also in the rock that contains the mesolite masses, and often the two can be seen in the same cavity. Indeed they are very intimately associated, and the green color of some of the most prized pebbles is due to this substance. It forms bands of color, and it fills triangular areas between the radiated forms of the spherulites when several spherulites are crowded together in one mass. It has a green glassy translucency, and its hardness is about that of mesolite. This mineral was analyzed by Miss Laura Linton and reported by Peckham & Hall with the following result. (1). Analysis (2) is by F. L. Sperry.

	(1)		(2)
SiO_2	40.21		44.53
Al_2O_3	30.21		27.36
CaO	10.37		9.90
Na_2O	4.06		5.92
K_2O	0.49	MgO	0.26
H_2O	13.75		13.08
FeO	0.40		
	99.89		101.05

It was considered by them as a form of the same mineral (mesolite) and was classed by Dana with thomsonite, to which all of these Terrace point zeolites were referred.

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Although on chemical grounds this mineral is referable to mesolite, or to thomsonite, it differs from both in optical characters.

Its axial plane is not perpendicular to the elongation. Its acute bisectrix is n_g, and the acute optic angle is very small. Its elongation is negative, i. e. parallel with n_p. Its refraction is less than that of thomsonite, and its double refraction is nearly that of quartz. Its angle of extinction varies from 0° to 19°, and its fibres are short and irregular in form, their width being about one third or one fourth their length, without rectilinear boundaries. Sp. Gr. 2.372.

For the purpose of making an approximate measure of the double refraction of this mineral a slide was prepared on which were ground simultaneously to the same thinness, four plates of barite, two of scolecite and a pebble of lintonite (625B) the last being in the center. In the fine massive, almost granular lintonite the highest color, being that presented by sections parallel to the axial plane, compared with the color given by the barite in similar position, shows that the double refraction of lintonite is about 0.017 to 0.018, that of thomsonite being 0.028. Such comparison is easily made by the use of the colored "tableau des birefringences" of Michel Levy, contained in the work *Mineraux des Roches*. A comparison with scolesite cut in the same position gives the same result.

This mineral has nearly the same optical and physical characters as jacksonite, but in chemical composition and specific gravity these minerals are quite distinct. The position of the optical plane parallel to the fibres allies lintonite with jacksonite.

Localities of Lintonite. It was found first at Terrace point. It is found in the same association at Eclipse beach, where it forms a casing that surrounds the mesolite masses, the mesolite radiations penetrating it. It is also found on the north side of Isle Royale.

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[European and American Glacial Geology Compared, XI.]

PRIMITIVE MAN IN THE SOMME VALLEY.

By WARREN UPHAM, St. Paul, Minn.

Going north from Paris, we stopped next, on August 16th and 17th of last year, at Amiens and Abbeville in the Somme valley, and saw well the physical and geologic features of this valley along the distance of about fifty miles from Amiens to its mouth, at the southeast side of the expanse of shallow sea called the Channel, which separates France and England. During the past half century this valley of the river Somme has been more fully studied and discussed by geologists than Moel Tryfan, Glen Roy, or any other locality that we visited. Besides the geologic and archæologic questions here especially considered, Amiens, the chief city of ancient Picardy, rewards the tourist in its magnificent old cathedral, its good public library, and its museum, rich in remains of the Bronze age and of ancient Roman and medieval times; and Abbeville, a smaller but very interesting city, has the church of St. Wolfram and the museum of Boucher de Perthes, occupying the house in which that famous archæologist lived.

At Abbeville and its northwestern suburb, Menchecourt, about sixteen miles from the river's mouth, Boucher de Perthes first proved by his researches in the valley gravel deposits, published in 1847 and later, that man was contemporaneous with numerous species of great mammals which have since become extinct, as the mammoth, woolly rhinoceros, and Irish elk, and with others which long ago ceased to live in France but are still found in far northern and arctic regions, as the reindeer and musk sheep, or in Africa, as the hippopotamus, hyæna, and lion. These discoveries led Dr. Rigollot, of Amiens, to search in the similar but higher gravel excavations close southeast of that city, at St. Acheul, where he found rudely chipped flint implements and bones of extinct animals associated together and occurring most frequently, as at Abbeville, in the basal part of the gravel and sand deposits. Rigollot published his observations in 1854; and Boucher de Perthes issued the second volume of his principal work in 1857, and his final third volume in 1864, four years before his death.

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It is difficult for us, at the present day of increased knowledge, to comprehend the general incredulity, prejudice, and reluctance, which the evidences of the great antiquity of mankind met and overcame. Little attention, indeed, was granted to these observers until they were visited and their conclusions confirmed by English archæologists and geologists, Falconer and Prestwich in the autumn of 1858, and Evans and Lyell in 1859. Their writings, with those of Lubbock and Alfred Tylor, also of England, Gaudry and others in France, and Dr. Edmund Andrews, of Chicago, all examining the Somme gravels, loesslike loam, and peat, during the decade of 1858 to 1867, established beyond question a human antiquity far earlier than the beginnings of written history and contemporaneous with great climatic and geographical changes in Europe. Only within recent years, however, since the origin of the glacial drift through the agency of land ice-sheets, and the late termination of the Glacial period, no more than 10,000 to 5,000 years ago, have come to be generally recognized, are we enabled with confidence to correlate that prolonged time of fluctuating glaciation of the northern lands on both sides of the Atlantic with the Palæolithic period, represented by the Somme gravels, by the similar implement-bearing deposits of many other valleys in France, Belgium, and southern Britain, and by the reindeer-hunting cave-dwellers in those countries.

In this paper, based on my examination of the Somme valley, the Palæolithic and Glacial periods are shown to have been nearly coextensive in duration. But a ruder and earlier stage of stone-working, which is named the Eolithic period, had preceded the Ice age, as is shown by the yet more primitive and geologically older flint implements found by Harrison and Prestwich on the upland plateaus of Kent and adjoining counties in southeastern England. Kent lies 50 to 100 miles northwest from the mouth of the Somme, and apparently had a land connection with France in preglacial times across the present strait of Dover, so that doubtless Eolithic men had likewise lived in the Somme region during that Late Pliocene or Early Pleistocene time, long before the maximum extension of the European ice-sheet. When the Glacial period was waning, the latest Palæolithic men of

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western Europe appear to have there exterminated most of the species of large mammals already mentioned, through persistently hunting them for food, so that at last this people, destitute of metals, but skillful in making implements of stone, bone, and horn, and having even a high artistic taste in carving figures of animals on horn and ivory, became mainly restricted, in providing food, to the sea borders, living in the greatest numbers in Denmark, and subsisting on smaller game, fish, and especially littoral marine mollusks. whose shells form the principal mass of the very remarkable kjökkenmöddings (kitchen-middens) of the Danish coasts. About the time of the recession of the ice-sheet from the Mecklenburg or Baltic moraines, described by the sixth paper of this series, another race or group of peoples, more advanced toward civilization, having attained the art of polishing their stone implements, tending herds and practising agriculture in some degree, and bringing with them domestic animals and cultivated plants derived from wild species in the fauna and flora of western central Asia, immigrated and took possession of Europe, supplanting and probably mainly exterminating the old Palæolithic people. This great immigration, ending the Palæolithic and inaugurating the Neolithic period, was probably the dispersal of the Aryans, who, as shown by the researches of philologists, carried throughout Europe languages of close affinity with those which at the same time or partly later spread also through Persia and India.

The men of the Somme gravel deposits belonged, if I rightly interpret the geologic record, to the early part of the Glacial period, previous to its culmination; the inhabitants of the caverns of Dordogne, in southwestern France, possessing greater skill in the manufacture of flint implements and adding others of bone and horn, hunting herds of wild horses and reindeer, seem correlative with the maximum stage of glaciation; and later these people spread northward, following the retreating ice-sheet to the boundary of its Mecklenburgian stage. De Mortillet and Cartailhac, as archæolgists, divide the Palæolithic period of France into four epochs or stages, succeeding one another as follows: 1, Acheulian, named from St. Acheul (or Chellean, from Chelles near Paris); 2, Mousterian, from Le Moustier in Dordogne; 3, Solutrian, from So-

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lutré in Burgundy; and 4, Magdalenian, from the caves of La Madeleine in Dordogne. These time divisions are characterized by increasing variety and excellence of the implements made, and by concomitant changes of the fauna. The implements found in the Somme valley are referable only to the earliest stage, which had at first a mild and moist climate, changing afterward to severe cold, with thick ice on the rivers in winter, broken and floating large blocks of rock in spring. Let us now examine the geologic origin and deposits of this valley in their relation to these stages of archæologic development, comparing both records with the ascertained history of the Ice age in the British Isles and northern Europe, and with estimates of its duration and that of the Postglacial period.

Above Amiens the Somme basin has been eroded to an undulating surface of broad but low hills and ridges, and is drained by several streams which converge in and near that city, being the sources of the supply of the Pleistocene gravels extensively excavated at St. Acheul, St. Roch and Montiers, which are situated respectively in the southeastern, western, and northwestern environs of the city. From Amiens to the sea the valley is troughlike, with a bottomland from a half mile to a mile and a half in width, down to Abbeville, and thence widening to three or four miles at its mouth, inclosed usually by very gentle or moderately steep slopes, but in a few places bordered by a steeper or precipitous bluff formed through direct undermining by the river at some time during the slow process of the valley erosion.

The river at Amiens is about 65 feet above the mean tide sea level; at Montiers, 58 feet; and at Abbeville, about 15 feet, the high tides having formerly reached above the city, until held back by the engineering improvements of the river course which now restrict its once meandering and dividing waters to a single straight canal along its next nine miles. The bottomland is mostly no more than two to five feet, and in its highest parts about ten feet, above the river in its ordinary low water stage. Along nearly all the distance below Amiens, it has large tracts of peat, from 10 to 30 feet in depth, thus extending far beneath the level of the river, or even, in the vicinity of Abbeville, beneath the sea level. During many centuries the peat has been excavated for fuel, and many

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small ponds, or moats, as they would be called in New England, occupy these hollows, and in other places mark abandoned parts of the earlier river channel. Since the close of the Glacial period, the Somme valley has received too little alluvium to keep pace with the slight epeirogenic depression which has been in progress; but at the mouth it has been filled by the coastwise drift of sand from the marine shore erosion, and by the muddy sediments deposited from inflowing tides.

On each side of the valley the upland extends far away in a great plainlike expanse, as seen in any wide view, though everywhere somewhat undulating, with an elevation of 150 to 250 feet above the river and its bottomland. Rounded outlines descend to the Somme and to the ramifying tributary streams, betokening a prolonged period of subaërial denudation by rains, rills, brooks and the main river, quite unlike the sharp-crested bluffs eroded, for example, in the glacial drift along the similarly deep Minnesota river valley and other valleys cutting thick drift plains in the upper part of the Mississippi basin. The Somme, lying south of the European glaciated area, has in its gravel deposits only materials derived from its own drainage basin, which consists of approximately horizontal Cretaceous strata of chalk, with concretionary flint nodules, and here and there overlying remnants of Eocene sand and clay, locally hardened to sandstone and shale. Residuary clay or loam, left in the process of denudation, covers the upland surface to a depth varying generally from two or three to six or eight feet.

The erosion of the Somme valley to essentially its present width and depth seems to me attributable to the work of the river during the very long Miocene and Pliocene periods, and to have been completed nearly as now before the great epeirogenic uplift causing the Ice age, which probably raised the British Isles and northern France at least 1,500 feet to 2,000 feet higher than now, while southwestern France and the Spanish peninsula appear to have been elevated much more. The evidences of this very great general uplift of western Europe were stated in the seventh paper of this series.* The record of the Glacial period here appears, in

*Am. Geologist, XXII, 101-108, August, 1898.

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my view, to be almost wholly represented by deposition of the gravel and sand on the lower flanks of the valley slopes, chiefly adjoining the mouths of tributaries; and it is in the older of these gravel beds that the flint implements occur, indicating the sojourn of men there at the beginning and through the early part of the Ice age.

In referring the valley erosion thus to middle and late Tertiary times, I agree with Alfred Tylor, whose careful discussions of this valley and those of southern Britain have hitherto received less attention than they deserve, probably because they differ from the earlier published views of Prestwich, Lyell, Lubbock, Evans, and others, who ascribe the excavation of the lower part of the Somme valley to river action during the Palæolithic period, while the later gravel beds were being deposited, or in the intervals of such deposition and afterward.* The Tertiary erosion extended through

*Without attempting reference to all of the multitude of papers and books relating to the evidences of primitive man in the Somme valley, citation of some which are more important or comprehensive may be noted as follows:

Boucher de Perthes, Antiquités Celtiques et Antédiluviennes,, vol. I, pp. 628, with 80 plates (1600 figures), 1847; vol. II, pp. 511, with 26 pls. (500 figs.), 1857; vol. III, pp. 681, with 12 pls. (104 figs.), 1864.

Sir Joseph Prestwich, Proc. Roy. Soc., 1859; Phil. Trans., 1860, 1864; many later papers, especially in Quart. Jour. Geol. Soc.; and his Geology, vol. II, 1888.

Sir Charles Lyell. Brit. Assoc. Report, 1859, Pt. 2, pp. 93-95; The Geological Evidences of the Antiquity of Man, 1863, chapters VII and VIII.

Sir John Lubbock, numerous papers, 1861-1864; Pre-historic Times, 1865, 1869, chapter XI.

Sir John Evans, Archæologia, 1862, pp. 28, with four plates; numerous other papers; and Ancient Stone Implements, Weapons, and Ornaments, of Great Britain, 1872 (exceedingly useful in its fullness of bibliographic references).

Prof. W. Boyd Dawkins, numerous papers, 1862 and onward; Cave Hunting, Researches on the Evidence of Caves respecting the Early Inhabitants of Europe, 1874.

Alfred Tylor, Quart. Jour. Geol. Soc., vol. XXII, 1866, pp. 463-468; vol. XXIV, 1868, pp. 103-125, with two plates (map of Amiens and vicinity, and 13 sections), and 13 figures (sections, profiles, and a map) in the text [same also in the Am. Jour. of Science, second series, vol. XLVI, pp. 302-327, with plates, Nov., 1868]; and vol. XXV, 1869, pp. 57-100, with six plates (abstract and discussion of this paper in vol. XXIV, pp. 455, 456).

Dr. Edmund Andrews, Am. Jour. Sci., second series, vol. XLV, pp. 180-190, March, 1868.

Prof. James Geikie. The Great Ice Age and its Relation to the Antiquity of Man, 1874, 1877, 1894; Prehistoric Europe, 1881.

Prof. Gabriel de Mortillet, Matériaux pour l'Histoire Primitive et Naturelle de l'Homme, 1865 and onward; Le Prehistorique, 1883.

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a duration of probably one or two million years, which would permit the valley to have its origin chiefly by rock solution. as the deepening of the excavation to 200 or 250 feet would be at an average rate of no more than an eighth or a third of an inch for each century.

When the more rainy and snowy climate of the Glacial period caused larger floods of the streams, especially during the spring months, the residuary loam and gravel mantling all the surface were subjected to exceptional denudation. Considerable material was swept down every stream course and ravine, until, on debouching into the main valley, the flood could expand more widely and so lose its velocity and transporting capacity. The gravel and sand were then deposited along the border of the broad bottomland and in alluvial fans upon the lower part of the inclosing slopes wherever tributary streams or the rills of rains and snow-melting descended.

Instead of forming continuous, level-topped terraces, at successive hights, up to nearly equal vertical limits on each side of the valley, like the terraces of modified drift on the Connecticut river along its upper half where it is the boundary between New Hampshire and Vermont, or like the usually less numerous terraces of this kind in most valleys of glaciated countries, the Somme gravel and sand are of less amount and have gentle or steep slopes toward the center of the valley, presenting a terrace escarpment only where

Emile Cartailhac, Matériaux, 1865 and onward; La France Prehistorique, 1889.

J. Ladrière, Annales de la Société Géologique du Nord, vols. XVIII-XX (summarized in Geikie's Great Ice Age, third ed., 1894, pp. 629-637).

Albert Falsan, La Période Glaciaire étudiée principalement en France et en Suisse, 1889.

Prof. Daniel Wilson, Prehistoric Man: Researches into the Origin of Civilisation in the Old and the New World, 1862, 1865, 1876.

James C. Southall, The Recent Origin of Man, as illustrated by Geology and the Modern Science of Prehistoric Archæology, 1875.

Prof. Alexander Winchell, Preadamites: or a Demonstration of the Existence of Men before Adam; together with a Study of their Condition, Antiquity, Racial Affinities, and Progressive Dispersion over the Earth, 1880.

Prof. G. Frederick Wright, The Ice Age in North America and its Bearings upon the Antiquity of Man, 1889; Man and the Glacial Period, 1892.

Prof. Daniel G. Brinton, Races and Peoples: Lectures on the Science of Ethnography, 1890.

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marginal parts of these deposits have been later carried away by the undermining action of the streams which brought them or of the main river. Along the Connecticut river a wide flood plain of modified drift was built up, filling the valley, to the level of the highest continuous terraces, 100 to 200 feet above the river; and the terraces are remnants of that flood-plain and of the lower temporary levels occupied and abandoned by the river during its process of removal of the greater part of that original deposit of the modified drift. Above the highest terraces of the main Connecticut valley, however, some of its tributaries, exceptionally supplied with drift from the drainage of the contiguous receding ice-sheet, formed lateral deposits, terrace plains and alluvial fans, as at North Haverhill and in other places south to Hanover, N. H., ranging in hight from 40 to 250 feet above the valley terraces, analogous in their mode of deposition with the Somme gravels.* In the Somme valley the supply of material was less than that set free from the melting North American ice-sheet, and it was insufficient to build up a flood-plain in any part of this valley below Amiens, though at many places it formed extensive deposits on either side, which sometimes reach, with slopes nearly like those inclosing the valley, from the bottomland up to hights of 50 to 100 feet; and patches of similar gravel and sand occasionally are observable also at greater hights, nearly to the verge of the uplands.

Levelling done for Mr. Alfred Tylor by the railway engineer, M. Güillom, gave the altitudes of the bottom and the original surface of the large St. Acheul gravel pits (two are each a quarter of a mile long), the richest in flint hatchets among the numerous excavations in and near Amiens, as respectively 140 and 160 feet above the sea, or about 75 and 95 feet above the river, which is a half mile distant to the north. The pits are not at the upper limit of the gravels, for Tylor remarks that "the sections near Amiens show the valley-gravel continuous from a height of 200 feet, at St. Acheul * * * to the River Somme (coated over by a nearly uniform warp of loess), and laid at a low gradient not exactly parallel to the surface of the chalk, but rather in its concavities." These higher gravel beds, however, having no exca-

*Geology of N. H., vol. III 1878, pp. 29-38, with maps and sections.

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vation, it is not known whether they contain stone implements and fossil bones; but generally, according to Ladrière, these are absent or rare in the highest beds of the valley gravels throughout northern France. In the vicinity of Montiers, one to two miles northwest of Amiens, nine gravel pits, containing worked flints and bones of extinct animals nearly as at St. Acheul, are shown by Tylor's description and map to range in hight from 77 to 155 feet above the sea, or from 17 to 95 feet above the Somme, the upper limit of the excavations being the same in relation to the river as near St. Acheul. The distinction of upper and lower gravel deposits, which Prestwich and Lyell made prominent in their writings, was pronounced by Tylor, as it seems to me with sufficient reasons, to be seldom definitely observable, the series, where developed at considerable hights, being usually continuous thence down nearly or quite to the bottomland and river.

Ladrière, who in 1875 and ensuing years has extensively examined and described the Pleistocene valley deposits of the Seine, Somme, and other river basins of a wide region extending northward into Belgium, divides these deposits into three somewhat similar series, successive in age and stratigraphic order, each of which can be traced from the bottoms of the valleys up to the plateaus, though not to their greatest hights. These series, each consisting of a regular sequence of gravel, sand, loam or loess, etc., representing three distinct stages of the Pleistocene period, are doubtless to be correlated with stages of advancing glaciation, interrupted by times of decrease and recession of the European ice-sheet. The researches of Ladrière thus present a record of climatic changes south of the glaciated area, by which geologists may very satisfactorily connect the evidences of primitive man in France with the time divisions of the Glacial period. His detailed notes of each of the three Pleistocene series and stages recognizable in these valleys are fully quoted by Prof. James Geikie in the third edition of the "Great Ice Age" (1894, pp. 630-632), from which it appears that flint implements of the Acheulian or Chellean type occur throughout the lower series; that such implements are also found in the middle series, but probably, as Ladrière thinks, through derivation from the older and stratigraphically lower beds; and

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that the infrequent implements found in the upper series are of the later developed Mousterian type.

We may infer, additionally, that while the still later Solutrian and Magdalenian types of implements were being developed, in the progress of the Palæolithic period, more moderate climatic conditions prevailed in northern France, with no important contribution to the valley gravels. These threefold deposits therefore appear referable to early stages of the Ice age, probably the Albertan, Kansan, and Illinoian, or rather to the European representatives of these stages. During the very long interval that ensued, previous to the Iowan or Polandian reädvance of glaciation, the Palæolithic men of western Europe passed through their Solutrian and Magdalenian stages; and shortly afterward, about the time of formation of the Wisconsin or Mecklenburg moraines, these men, destitute of metals, of agriculture, or of domestic animals, were practically crowded off from Europe, famished by extinction of the large species of game, and driven out, exterminated, or absorbed, by the immigrating Neolithic people. The invaders, as before noticed, though ignorant of the most useful metals, brought wheat and barley, cattle, sheep, goats, and swine, and, most significant in linking them with later written history, the Indo-European languages. Their arrival and settlement, and the end of the Palæolithic period, preceded the departure of the ice-sheet from Scotland and Scandinavia, where no Palæolithic types of stone implements are found, although Neolithic types abound and are collected in immense numbers.

Sections of the Somme gravels at Menchecourt, Mautort, and other localities near and below Abbeville carry back the Acheulian stage of Palæolithic time quite to the beginning of the Ice age. The many other sections in this valley display ice-floated sandstone blocks and deformations of the strata attributable to the melting of masses of river ice; but these disturbed conditions were absent when human implements and the bones of the mammoth, the woolly rhinoceros, wild horse, urus, stag, reindeer, lion, and hyæna, were mingled in the Menchecourt gravel and sand beds, which are about 20 to 30 feet above the sea level, under subsequent deposits of 20 feet of loam and clay, the surface being about 50 feet above

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the sea or 40 feet above the river. The sections of Menchecourt, Mautort, etc., are further distinguished from others at higher levels near Abbeville, and from all at both low and high levels along the upper part of the valley, by their containing marine shells. Lyell writes of their mode of occurrence at Menchecourt as follows:

> In the lowest beds of gravel and sand in contact with the chalk, flint hatchets, some perfect, others much rolled, have been found; and in a sandy bed in this position some workmen, whom I employed to sink a pit, found four flint knives. Above this sand occur beds of white and siliceous sand, containing shells of the genera Planorbis. Limnea, Paludina, Valvata, Cyclas, Cyrena, Helix, and others, all now natives of the same part of France, except Cyrena [Corbicula] fluminalis, which no longer lives in Europe, but inhabits the Nile and many parts of Asia, including Cashmere, where it abounds. No species of Cyrena is now met with in a living state in Europe. Mr. Prestwich first observed it fossil at Menchecourt, and it has since been found in two or three contiguous sand-pits, always in the fluvio-marine bed.
>
> The following marine shells occur mixed with the fresh-water species above enumerated: Buccinum undatum, Littorina littorea, Nassa reticulata, Purpura lapillus, Tellina solidula, Cardium edule, and fragments of some others. Several of these I have myself collected entire, though in a state of great decomposition. . . . They are all littoral species now proper to the contiguous coast of France. Their occurrence in a fossil state associated with fresh-water shells at Menchecourt had been noticed as long ago as 1836 by MM. Ravin and Baillon, before M. Boucher de Perthes commenced the researches which have since made the locality so celebrated. The numbers since collected preclude all idea of their having been brought inland as eatable shells by the fabricators of the flint hatchets found at the bottom of the fluvio-marine sands.

This part of western Europe was then slightly lower than now, indicating, with the absence of ice before noted, that the time represented by these sections preceded the great uplift of this region which culminated in the maximum European glaciation. But earlier, and probably continuing with increased vertical and geographic extent during the early part of the Ice age, the general epeirogenic uplift of the continental area bridged the strait of Gibraltar and the center of the Mediterranean sea from Tunis to Sicily and Italy, as shown by Dawkins and Geikie, raising the land in both regions about 2,000 feet higher than now, and affording a passage to the great African mammals. They also crossed where the shal-

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low strait of Dover now is, entering Britain; and during the oncoming and culmination of the Ice age the British Isles were united with the continent by a very broad land surface, reaching far west of the Channel and occupying the basin of the North sea and nearly all the area between Scotland and Norway, until the Scandinavian ice-sheet covered that land plain to northeastern England.

Our estimates of the duration of the Postglacial period are based on computations by Andrews from the shore erosion and beach sand accumulation of lake Michigan; on his investigation, before cited, of the age of the peat beds in the Somme valley and of the alluvial fan deposits of the Tinière, tributary to lake Geneva, which latter had been differently interpreted by Morlot; on the study of the recession of the falls of St. Anthony by Prof. N. H. Winchell; on that of Niagara falls by Gilbert and others; on Dr. Robert Bell's observations of the extent of subaërial erosion of limestone rocks in Canada; and on many other careful studies in both North America and Europe. These estimates concur so well that the duration which they give approximately as between 5,000 and 10,000 years may be confidently accepted as the measure of Postglacial time. It may be otherwise and better stated that the departure of the ice-sheets on these continents probably occupied some 5,000 years, known as the Champlain epoch from marine deposits overlying the glacial drift in the basin of lake Champlain; and that it was completed, nearly as now, about 5,000 years ago, with remnants of the old ice-sheets lingering ever since in Alaska and Greenland and on the mountainous plateaus of Norway. The incursion of the Neolithic men and doom of their Palæolithic predecessors belong thus probably 6,000 or 7,000 years ago.

The duration of the Ice age cannot be so reliably determined; but the researches of Geikie, Chamberlin, and many others, convince us that on both sides of the North Atlantic glaciation was approximately synchronous, with parallelism in its beginning, fluctuations, and end, through a period ten to twenty times as long as that which has followed it, or of somewhat such ratio. In other words, the Glacial period, from the time of the Palæolithic men at Menchecourt and St. Acheul to the Neolithic immigration and the not widely later re-

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treat of the ice-sheet in Scotland, Sweden and Norway, measured probably 50,000 or 100,000 years.

It is therefore right that the Acheulian men should be termed primitive. They had not learned how to use the Creator's gifts. The power of invention, ready to bestow dominion and utilization of animate and inanimate nature, lay dormant and was scarcely beginning to awaken; but even then the men in the Somme valley were doubtless mentally and physically developed far nearer to ourselves than to the mist-covered morning and dim dawn of the earliest human divergence from an ancestral anthropoid species perhaps ten or twenty times more ancient.

On leaving Abbeville, our journey continued through Boulogne, Calais, Dover, and Canterbury, to London. Again in that great city, a few days were spent in its libraries, museums, parks, and in excursions to the outlying country. Then we embarked at Southampton, eighty days after our landing there; arrived in New York on August 27th; and, after visiting eastern friends, reached home in St. Paul on September 9th, bringing memories, experience, and note-books of the summer of 1897, long planned for and happily completed.

THE GREAT TERRACE OF THE COLUMBIA AND OTHER TOPOGRAPHIC FEATURES IN THE NEIGHBORHOOD OF LAKE CHELAN, WASHINGTON.

By Israel C. Russell, Ann Arbor, Michigan.

In an article by Mr. William L. Dawson, on "Glacial phenomena in Okanogan county, Washington," published in the October number of this journal, exceptions are taken to my measurement of the hight of the great terrace of the upper Columbia, and to certain conclusions based on my reconnoissance in central Washington in 1892. Having made a second journey through the Lake Chelan region during the past summer and obtained additional data in reference to its surface geology, I feel that I am qualified to reply to Mr. Dawson's criticisms, and to offer in return a few suggestions in reference to his interpretations of the history of some of

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the more striking features in the topography of that most interesting country.

The Great Terrace of the Columbia. In my report of 1892* the great gravel terrace, bordering the Columbia in the neighborhood of lake Chelan and occurring at many localities further up the Columbia, was briefly described and the elevation of its surface above the river stated to be 700 feet. This is an aneroid measurement, or rather the mean of several such measurements, and I believed, at the time, was as accurate as the method employed could be expected to yield, especially when opportunities for rating the barometer could be had only at wide intervals. Mr. Dawson states positively that the great terrace is but 300 feet above the Columbia; whether this is an aneroid measurement or the result of some more accurate method is not recorded.

During the past field season I again examined the great terrace referred to, at various localities from the mouth of the Methow southward along the Columbia, to where it terminates a few miles south of the mouth of Chelan river. The terrace is especially well displayed at the mouth of the Methow, where it forms a plateau fully a mile-and-a-half broad. I again measured its hight, using an aneroid in which I had learned to place much confidence. This measurement was in duplicate, one set made on descending from the surface of the terrace to the river and the other on returning; the reading on the return was the same as at the start. These observations gave 550 to 560 feet as the hight of the surface of the terrace above the river. On the uplands bordering the great terrace, at the locality just referred to, there are other terraces about 100 feet higher, but these belong in another category and have a different history than the great terrace. The surface of the great terrace is in several places quite irregular, on account of the settling of the material composing it so as to form basins, but in general slopes gently from the bordering uplands to the broken escarpment overlooking the river. This difference where the terrace is broad amounts to fully 100 feet. Another measurement of the hight of the great terrace, at a locality about five miles south of the mouth of

*Bulletin No. 108, U. S. Geological Survey.

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the Methow, gave an elevation of 570 feet. Still other aneroid readings on the great terrace farther down the Columbia, without, however, descending to the river, but referring back to the reading obtained at the mouth of the Methow two days previous, gave an elevation of 660 feet. This discrepancy of about 100 feet, I believe to be due mainly to changes in atmospheric conditions.

The great terrace referred to above is, without question, a portion of the same terrace visited by me in 1892, below the mouth of Chelan river and on the left bank of the Columbia. As previously stated, the hight above the river there obtained by aneroid, was 700 feet. This measure is probably somewhat too high, judging by the observations made by me this year, and may perhaps be 100 feet in error, but as the hight of the terrace above the river probably increases somewhat as one follows it down stream, I doubt if the probable error is as much as just stated. Mr. Dawson assigns an elevation of but 300 feet for the great terrace above the river, and the difference between our determinations is from 250 to 400 feet. This wide discrepancy is the more surprising as the difference between the elevation of the Columbia at the mouth of Chelan river, and the surface of lake Chelan, as determined by Mr. Dawson, and by myself in 1892, is the same, namely 325 feet.*

In volume one, of the reports frequently termed the "Pacific Railroad Surveys," there is a paper of Professor George Gibbs, in which the Terrace in question is referred to as follows, (page 483):

"On leaving the Columbia to visit the Chelan lake, our route ascended one of these terraces, rising to a height of six hundred and forty feet in a single slope, and occupying a recess in the hills which bordered it. On reaching the top, it proved to be the entrance of a level valley, extending through the hills and emerging about one hundred and fifty feet above the lake."

As correctly stated by Mr. Dawson, the great terrace of the Columbia is a true stream terrace. It is one of a large

*Recent measurements with engineer levels, made by the Topographic Division of the U. S. Geological Survey, show that the surface of lake Chelan is 1078 feet, and the mouth of Chelan river 670 feet above the sea; the difference is 408 feet.

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series of similar terraces which occur along many of the rivers of eastern Washington. There is a similar great gravel terrace in the canyon of Snake river, another along Spokane river, and other in the valleys of the Okanogan, Methow, Yakima, etc. These several terraces have many features in common, but as they have not been adequately studied, more information concerning them is necessary before their histories can be interpreted with confidence. All the streams referred to, however, flow to the Columbia and converge toward the depressed region in east-central Washington. In all cases thus far observed, also, the terraces are conspicuous on the upper course of the rivers where their valleys or canyons are narrow, and disappear lower down the river where their valleys become broad. For example, on following the Columbia southward from the mouth of Chelan river, the valley soon broadens and one looks in vain for the great gravel terrace so conspicuous farther up stream. This termination of the great terrace of the Columbia when traced down stream is one of the reasons for believing in the former existence of a lake in the basin-like portion of south-central Washington. This water body was named lake Lewis by Symons, but full and unquestionable evidence of its actual existence can not be said to have been discovered. With lake Lewis filling the valley of the Columbia below where the great terrace terminates, we are enabled to give a natural interpretation of the great gravel deposit in the valley of the upper Columbia. That is, the Columbia discharged into lake Lewis, and built a delta of coarse material, being, as I am inclined to believe, overloaded with debris like many other rivers in the same general region, on account of the changes in conditions accompanying the Glacial epoch. With the building of the delta the river channel, up stream from it, became deeply filled with gravel, and after the waters of lake Lewis were withdrawn, the Columbia excavated its present inner channel through the gravel, partially filling its old rock-cut valley.

This is in outline my interpretation of the history of the great terrace of the Columbia, but as only a portion of the field has been studied and this in connection with reconnoissance work, I hold my conclusions lightly and am willing to change them if additional observations demand it.

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The Methow Glacier. In the article by Mr. Dawson, referred to above, it is stated that formerly three glaciers flowed eastward from the Cascade mountains and reached the Columbia; these ice streams "swept down the Chelan, Methow and Okanogan valleys, respectively." The evidence in reference to the Chelan and Okanogan glaciers, as is well known, fully confirms a portion of this statement, but, as to the Methow glacier, I wish to say that I followed the Methow river during my reconnoissance of last summer, from near its source at the crest of the Cascade mountains to its junction with the Columbia, and found abundant evidence of the former presence of glacial ice from the source of the river to Winthrup. At Winthrup the river receives an important tributary from the north, and its valley broadens. The former glacier expanded in this broader portion of the valley and reached some four or five miles south of Winthrup and deposited a fine group of kames with undrained basins between, some of which still hold lakelets. From the locality just mentioned to the mouth of the river I failed to find any evidence of the former presence of a glacier. The Methow glacier according to my observations did not reach within about 40 or 50 miles of the Columbia, and hence cannot be appealed to as having any connection with the origin of the coulée crossing the promontory on the east bank of the Columbia, opposite the mouth of the Methow. I refer to the so called "glacial channel" shown on Dawson's instructive diagram forming figure one, page 206, in the article under review. According to the explanation advanced by Mr. Dawson, the Methow glacier dammed the Columbia, and caused the river to rise "to a hight sufficient to enable it to cut across the corner, where it excavated a deep transverse channel some 150 feet down into the granite." The transverse channel referred to attracted my attention last summer, while on the opposite or west side of the river, but I did not visit it. Some of its features, however, may be better studied from a distance than by close inspection, as I believe will be shown by my interpretation of it made in the field. I therefore transcribe the following passage from my note book: "The great terrace occurs on each side of the Columbia and extends far up its course above the mouth of the Methow. Just opposite

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where the Methow comes in there is a bold rocky promontory, on the plateau-like surface of which there are a few crags rising above the level of the great terrace. This rock mass is separated from the mountains to the east by a coulée through which the Columbia or a part of its waters once flowed. The bottom of the coulée is below the level of the great terrace." The explanation of the origin of the coulée which presented itself to me, from the facts as I saw them, is, that the river when its channel was occupied from side to side by the gravel deposit now represented by the great terrace, was greatly expanded, being a broad, swift stream, and that a portion of its current followed the now abandoned coulée, leaving the crags on the surface of the mesa at the summit of the promontory, as islands. Later, when the Columbia re-excavated its channel, the branching passage in solid rock was abandoned. The river did not make the coulée, but simply modified its bottom to some extent. The origin of the coulée need not be discussed at this time but the fact that it is older than the great terrace is beyond doubt. This explanation meets all of the conditions as I saw them, and is in harmony with the histories of other coulées, similar to the one described above, and besides is independent of the Methow glacier, which according to my observation did not come within at least forty miles of the region under discussion.

Antwine's Coulée: On the west side of the Columbia valley and south of the mouth of the Methow, there is a deep, narrow channel, similar in character to the one referred to above, but of much larger size, known as Antwine's coulée. As correctly stated by Dawson, Antwine's coulée connects the Methow valley at a locality about four miles above its mouth with the Columbia valley, some ten miles to the south. This deep, narrow defile is described by the author cited above as a glaciated channel, "which the ice has hollowed out between some sturdy outlying spur and its parent mountain."

I traversed the entire length of Antwine's coulée last September, but failed to find any evidence to suggest that it had once been occupied by a glacier. The narrow, steep sided trench is crossed from side to side by alluvial cones, and talus slopes, between which there are several undrained basins, three of which hold lakelets. The coulée is also obstructed by

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blocks of rock which have fallen from the bordering cliffs, but is entirely without glacial scorings, moraines or other evidence of ice work.

Below or south of the southern end of Antwine's coulée, as also stated by Dawson, there is another short coulée, similar in character to those just considered, the course of which in general, is parallel with the Columbia. The author just referred to, states that this coulée is about a mile in length and occupied at present by glacial debris. My study of the coulée in question, however, failed to show that it contained any glacial debris or that it was either produced or modified by glacial action. I did find alluvial cones, talus slopes, fallen blocks, etc., of the same character as those obstructing Antwine's coulée.

Knapp's Coulée: On the south side of lake Chelan, about three miles from its eastern end, there is another coulée, similar to those referred to above, known as Knapp's coulée. This is a deep narrow trench in a mountain mass that rises from 1800 to 2500 feet above the lake's surface, and has a length of four or five miles. Its general course is nearly at right angles to the trend of the eastern portion of Chelan valley, and at its southern end it opens out into the valley of the Columbia. In describing this channel and discussing its origin, Mr. Dawson states that: "It is an ice-hewn valley, a discharge pipe of the Chelan glacier. Originally consisting of two opposite valleys heading at near the same point on the divide, it was selected by the ice as presenting the easiest avenue of escape across the rampart; i. e., the lowest point, and was subsequently deeply excavated by the long continued and gradually concentrated ice-flow. To-day its superficial features of kettle-holes and morainic banks have not been obliterated or even noticeably modified by subsequent changes."

I traversed the entire length of Knapp's coulée last September, and, as in the similar instances cited above, failed to find any evidence of the work of ice; but I did find alluvial cones, talus slopes, and fallen blocks in abundance, together with undrained basins between the larger obstructions.

The relation of Knapp's coulée to the valley occupied by lake Chelan is in itself sufficient to show that the great Chelan

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glacier could not have divided so as to send a branching ice-distributary through it. The conditions as they existed at the northern end of the coulée during the maximum extension of the Chelan glacier, are paralleled, I think, in every essential particular at the present day, on the east border of Hayden glacier, near Yakutat bay, Alaska. At the locality referred to, a deep, narrow, transverse channel, a remnant of an ancient stream channel, cuts across a mountain spur. This channel is at right angles to the east border of the Hayden glacier, which forms a wall of ice from 150 to 200 feet high across its upper extremity but does not extend into it. A small stream, fed by the melting ice, courses down the lateral channel, but this is all the direct influence that the glacier has upon it. The Chelan glacier rose about 200 feet above the lowest point in the entrance to Knapp's coulée, but did not enter it. The melting of the ice very likely fed a small stream which found its way southward down the coulée, but of this I have no good evidence.

There are several other portions of Mr. Dawson's interpretation of the topographical history of the region drained by the Columbia, which differ widely from the conclusions based on my own observations, but it does not seem as if farther discussion at this time would be profitable. It is to be remembered that no detailed geological studies have been carried on in the portion of the country under consideration, at least my own work there is entirely of the nature of a reconnoissance, and the radical differences between Mr. Dawson's conclusions and my own, can, apparently, only be adjusted after more extended field-study.

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THE OCCURRENCE OF CRETACEOUS FOSSILS IN THE EOCENE OF MARYLAND.

By Rufus Mather Bagg, Jr., Ph. D., Colorado Springs, Col.

Two Cretaceous fossils, Terebratula harlani and Gryphæa vesicularis, were discovered last summer in the Eocene greensand while the writer was engaged in survey work for the State of Maryland. These forms, abundantly and characteristically developed in New Jersey, have been supposed to belong exclusively to the Cretaceous and so far as I am able to learn there is no record of their occurrence in post-Cretaceous deposits, if we except the doubtful report of the presence of Terebratula harlani in the Tertiary of South Carolina.

One of these fossils, Terebratula harlani, is in New Jersey confined to a narrow but definite zone of the Rancocas formation (Middle Marl bed) which averages only two feet in thickness and extends in a northeast-southwest direction across the entire state. The other, Gryphæa vesicularis, while found in all portions of the Monmouth formation, is, in the Ranocoas. limited to another definite zone beneath that of Terebratula harlani.

The specimens of Terebratula harlani which the author discovered in Maryland were found in the Eocene marl of Prince George's county in a bank by the roadside on Western branch of the Patuxent river about three miles west of Leeland, a small station on the Popes Creek railroad. The greensand at this cutting in the road is very fossiliferous and carries the common lower Eocene fauna, Ostrea compressirostra Say, Cucullaea gigantea Conrad, Cytherea ovata Rogers, and several others.

The Terebratulæ under discussion occur in the lower portion of the bank about eight feet above the bend of the road. They seem to have a limited vertical range of about five feet and are often grouped together in indurated lenses of the marl but they are by no means confined to these indurations. The shells are remarkably well-preserved, very large and thick, and many of them attain a maximum size for the species of two and three-quarters inches in width by three inches in length. These forms so closely resemble New Jersey

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specimens that they could not be distinguished from them if both were in the same tray. The Cretaceous marls which underlie the Eocene are at this locality on Western branch fully twenty feet below this level. Furthermore as these brachiopoda occur with such characteristic Eocene fossils as Ostrea compressirostra and Cucullæa gigantea there can be no question of the age of the deposit under consideration.

The second discovery was made in the bluffs of the Potomac river not far from Clifton beach on the Maryland shore where a perfect specimen of Gryphæa vesicularis showing both valves was obtained. The shell is identical with those so numerous in the Rancocas marl bed of New Jersey. An examination of these Cretaceous fossils shows that their inhabitants lived in the waters at the time the Eocene greensand was being deposited for none of the shells are waterworn in the slightest degree and the interior of the shell is filled with the same glauconite and sand grains of which the surrounding greensand is composed. In fact I not only believe that these organisms lived side by side with their Eocene associates but that they existed under most favorable conditions as their large size and thick shells attest.

A key to the explanation of their occurrence is, I think, to be found in the peculiar relation to the Terebratula and Gryphæa zones as they are developed in the state of Delaware. On the south bank of the Noxontown mill-pond their position is well seen. Throughout New Jersey these fossils occupy a constant position beneath the limesands of the Rancocas.

A generalized section of the New Jersey Rancocas is as follows:

Thickness in Feet.	Formation.		Name.	
10-20	Limestone and Limesand.		Vincentown Limesand.	
2-3	Terebratula harlani	Shell layers of Cook.	Sewell Marls.	
3-4	Gryphaea vesicularis			
5-20	Green Marl			

After crossing the Delaware river, although these beds continue southward, their position changes and we find the shell layers above the limesand. This is well seen along a large portion of the south shore of Noxontown mill-pond. If these limesands belong to the same period of deposition as

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in New Jersey, and there is no doubt but that they do, then we must conclude that the Terebratulæ and Gryphææ migrated southward as conditions became unfavorable for their existence in New Jersey and continued to survive in later time in Delaware. The development, however, of both the limesand and the shell-layers becomes diminished farther south and before reaching the Chesapeake bay become so greatly reduced that the beds are only occasionally observed and it is doubtful if they exist at all in portions of the belt. The shell-layers do occur on a branch of the Sassafras river called Swan creek on Mr. Jacob's farm. Upon the west shore of Chesapeake bay only one locality has heretofore been known where the Terebratulæ occur and this was mentioned by professor P. R. Uhler many years ago. The spot where professor Uhler discovered this brachiopod was at the base of the oxidized greensand bluffs opposite Annapolis. In place of the limesand and the shell-layers we find that the Rancocas formation in Maryland consists largely of glauconite grains and finely triturated sands which are more highly oxidized than the sands of the same formation in New Jersey. Furthermore, the glauconite is not so abundant, and in Maryland this bed has been dug for fertilizer in only a few places.

The writer's discovery of these fossils in Prince George's and Charles counties proves that these organisms not only continued their existence in the Eocene but that they migrated much farther southwest than has previously been supposed. Brachiopoda are rare in the Eocene of the Atlantic Slope and have never been recorded as occurring in Maryland. Even in New Jersey Cretaceous where such a wealth of mollusca exists only two species of brachiopoda are at all plentiful. These forms are the one under discussion and Terebratella plicata Say. The latter is a small form and occurs widely distributed throughout the Monmouth formation, being present in the Navesink marl bed and the Redbank sands. Terebratula harlani is, on the other hand, one of the largest and most beautiful of the genus found in America. Prof. R. P. Whitfield in his monograph of the Cretaceous Mollusca of New Jersey states that the shell has been obtained from

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South Carolina where it is said to be found in the Tertiary, but he then adds: "This I think extremely doubtful as it is never found above the Middle Marl beds of New Jersey."

We cannot suppose that this species of brachiopod, so abundant in a zone of the Rancocas marl bed disappeared at the close of this stage and reappeared again in the Eocene. Nicholson in his Manual says: "There is no record of the reappearance of any fossil after it has once disappeared. There are plenty of cases in which a species seemingly disappears in a particular set of rocks to reappear in some higher and later set of rocks in the same region, whilst its remains are wanting in all the intermediate deposits of the area. It also often occurs that the species, having disappeared in one region, is found in deposits of later age in another area." We may therefore infer that if the organism is lacking in intermediate deposits either the forms migrated to another region at that particular period or else the conditions were not favorable for their preservation.

The study of the migration of organisms which in the past have inhabited the earth has never been adequately worked out save in a few instances, but such a study would prove extremely interesting and profitable. That such migrations did occur and on a wide scale is strikingly shown by such brachiopods as Productus semireticulatus and Streptorhynchus crenestria, which occur in the lower Cambrian rocks of Europe, Australia, India, China and North America.

In other words, these forms under consideration must have migrated from place to place unless we suppose that they had a universal distribution in a universal ocean, a condition hardly probable. Inasmuch as sessile forms cannot migrate and because brachiopoda in adult life are attached, the migration of this group must have occurred when the forms were in their larval stage during which they possess the power of rapid locomotion. Any geological barrier might, however, have prevented a migration even of free-swimming forms into closely adjoining areas suitable for their existence. A cold current of water might act as such a barrier. We must also bear in mind that not all synchronous deposits disclose the

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same fauna and the difference becomes more marked if one deposit is marine and the other terrestrial.

The Cretaceous period in Europe was followed by elevation over wide regions, but because the elevation was gradual organisms were often able to migrate; but according to our present knowledge this place of transference is unknown. On the Atlantic slope, however, deposition went on over a gradually sinking area of the sea floor and the Eocene marls were laid down conformably on the underlying Cretaceous. In reference to this professor Dana in his revised Manual says (p. 821): "The upper Greensand group graduates without a break in the stratification into the overlying Eocene Tertiary as if its formation were like the upper Laramie, the closing work of the Cretaceous period."

It is quite possible that a cold current from the north may have swept along the Atlantic border at the close of the Cretaceous and either exterminated the mollusca or else driven it farther south though I am not certain that we have any proof of this. It is evident that professor Dana believed in this cold current acting as a barrier for on page 877 of his revised Manual he states: "If the change had made the arctic waters only 15° F. colder than they were during the Cretaceous period, the polar waters as they flowed southward, would probably have been exterminating to the greater part of the life of coast regions all along the shallower waters, and down to such depths as the cold current reached. Such a cause might make a complete break in the succession of species in a region, without any break in the succession of beds, as happened in New Jersey."

The writer believes that elevation of the coast line along the western border of the New Jersey Cretaceous early in Eocene time and a deepening of the waters farther south was one of the chief causes for this destruction of life although it is quite probable that cold currents coming southward may have completed this destruction. A study of the Eocene deposits of Maryland reveals the fact that the formation increases in thickness toward the southwest like a letter V turned sideways. The apex of the V was near the western

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corner of Noxontown mill-pond in Delaware while the other end reached the shore of the Potomac river near the mouth of Potomac creek.

While the upper and lower portions of the Eocene differ in the character of their fauna and in lithological composition sufficient to separate the formation into two divisions there is no doubt but that deposition went on continuously throughout the entire Eocene period and the increasing thickness southward is doubtless to be accounted for by supposing that the Cretaceous shore-line was more nearly stationary in central Delaware while the region farther south was undergoing more rapid and prolonged subsidence. In this way it was possible for the young of Terebratula harlani and of Gryphæa vesicularis to migrate southward and, passing beyond the Cretaceous limit, to continue its existence in the warm and deeper waters of southern Maryland. Whether the few feet of Eocene marl in New Jersey represents the entire period or not we cannot say, but inasmuch as there is a line of non-deposition in Delaware where the Miocene rests directly on the Cretaceous this line was either stationary or elevated while deposition was going on both to the north and to the south of this area. If this is not the case then there was a period of erosion in some stage of the Eocene, for the Miocene rests uniformly along the entire region from Shark river in New Jersey to southern Maryland. It is possible that more detailed study of the region of central Delaware will yield additional facts, though the author of this paper has made a pretty careful examination of all the available exposures in that state.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Maryland Geological Survey, Vol. I, 1897. WM. BULLOCK CLARK, State Geologist. The Johns Hopkins Press, Baltimore, Md.

The first report issued by the Maryland Geological Survey is of a preliminary character and the subjects treated are largely historical and introductory. Part I. discusses the establishment, plan of opera-

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tion and purposes of the survey. These last are a model of what a geological survey should propose to accomplish for the state which supports it. The suggestion of the publication of an elementary treatise, adapted to the purposes of public instruction is in line with the demands of the new geography. Acting upon this suggestion, Maryland could enable her youth, without added expense to the state, to reap the benefits of her peculiarly instructive physiographic and geologic conditions.

Part II. contains a historical account of all previous investigation of the physical features and natural resources of the state. This account includes an interesting sketch of the information acquired during colonial days of the physical features of Maryland.

More or less desultory investigation has been carried on since that time by individual scientists, among whom may be mentioned Lyell. Official investigation began under the auspices of the First Maryland Survey (1834-1841) and was continued by the State Agricultural Chemists (1848-1862), the Maryland Academy of Science (1855), the Maryland Agricultural College (1856) and Experiment Station (1887), and finally by the Geological Department of the Johns Hopkins University. With Dr. George H. Williams' connection with that institution (1883) began the period of most thorough and productive study of the geology of the state. The investigation thus inaugurated has been continued by Dr. Williams' associates and successors, and is now merged into that of the recently organized Maryland Geological Survey (1896).

An outline of the present knowledge of the physical features of Maryland is embraced in Part III. This is largely based upon the work of Dr. Williams and his associate and successor, Dr. Clark, together with the results of work accomplished since the organization of the new survey. This summary is free of references, and is a most clear and readable presentation of existing information.

A valuable and exhaustive bibliography and cartography of Maryland comprise Part IV. These were compiled mainly by Dr. E. B. Mathews and are rendered more serviceable to investigators by the addition of brief statements of the contents of the paper or character of the map.

The volume closes with a report upon magnetic work in Maryland (Part V.), prepared by Dr. L. H. Bauer, formerly of the U. S. Coast and Geodetic Survey. The magnetic elements have been determined at a number of points, and the results of the work will be of value to all land surveyors. This report also includes a brief account of the history and purpose of a magnetic survey.

The volume is well illustrated by seventeen lithographic maps and views, and the excellence of the typographic workmanship is unusual in publications of its kind. Maryland is to be congratulated not alone upon the contents, but also upon the prompt appearance and attractive form of the first report of her new geological survey.

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Vol. II., which will contain a description of the building and decorative stones of the state, is promised for the coming winter.

F. B.

Orthoclase as Gangue Mineral in a fissure Vein. By WALDEMAR LINDGREN. (*Am. J. Sci., 155, 418-420.*)

After noting the rather sparing occurrence of the feldspars in true veins, the author describes a silver-gold vein near Silver City, Idaho, having a gangue of quartz and orthoclase. The orthoclase is of the variety adularia, and the evidence of its aqueous origin is followed by an analysis yielding SiO_2, 66.28; Al_2O_3, 17.93; K_2O, 15.12; Na_2O, 0.25; undet., 0.42; total, 100.00. W. O. C.

Notes on Rocks and Minerals from California. By H. W. TURNER. (*Am. J. Sci., 155, 421-428.*)

This paper describes: 1. a peculiar quartz-amphibole dioryte, with very complete analysis of the dioryte and its component amphibole; 2. a new amphibole-pyroxene rock from Mariposa county; 3. a quartz-alunite, with an analysis of the alunite, which occurs as an efflorescence; 4, zircon from gravels; 5, molybdenite from several localities; 6, tellurium, selenium and nickel in gold ores; 7. carbonaceous material in quartz from gold veins east of the Mother lode; 8. berthierite from Tuolumne county. W. O. C.

Mineralogical Notes on Anthophyllite, Enstatite and Beryl (Emerald) from North Carolina. By J. H. PRATT. (*Am. J. Sci., 155, 429-432.*)

The anthophyllite and enstatite are from the great dunyte dikes of Western North Carolina; and two analyses of each are given. The emerald is from vein of pegmatyte in Mitchell county, and was not analyzed. W. O. C.

The Jerome (Kansas) Meteorite. By HENRY S. WASHINGTON. (*Am. J. Sci., 155, 447-454.*)

This meteorite, about 65 pounds in weight, is a deeply oxidized mass, made up of numerous chondrules of bronzite and olivine, with fragmental crystals of these minerals and pyroxene, and small angular masses of nickel-iron (4.3 per cent.). No troilite was recognized, but the analysis indicates that it was originally present to the extent of 5.2 per cent. An approximate chemical analysis and an analysis of the nickel iron, which contains 10.01 per cent. of nickel, are followed by exhaustive analyses of both the soluble and insoluble portions; and from these analytic data the mineralogical composition is calculated, the chief constituents, in order of abundance, being olivine, bronzite, limonite (secondary), oligoclase, troilite, pyroxene, nickel-iron and orthoclase. W. O. C

On the Origin of the Corundum associated with the Peridotytes in North Carolina. By J. H. PRATT. (*Am. J. Sci., 156, 49-65.*)

The peridotyte (dunyte or olivine rock) is a basic, magnesian, plutonic rock forming lenticular dikes and bosses in gneiss, and the corundum is invariably found on the borders of these masses, between

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the dunyte and gneiss. The author's conclusion, which appears to be well sustained by the facts, is that the corundum is not in any sense a secondary mineral, but dates from the original solidification of the dunyte, having existed in solution in the molten mass of the dunyte at the time of its intrusion and separated out among the first minerals as the mass began to cool. The dunyte magma, holding in solution the chemical elements of the different minerals, would be like a saturated liquid, and as it began to cool the minerals would crystallize out, not according to their infusibility, but according to their solubility in the molten magma. The more basic portions, according to the general law of cooling and crystallizing magmas, being the most insoluble, would be the first to separate out. These would be the oxides containing no silica, such as chromite, spinel and corundum. The important experiments of Morozewicz with molten basic glasses are cited as fully corroborating this view; and it is noted that the crystallization of the corundum and other oxides would begin on the outer border of the mass where cooling was most rapid. Convection currents would then tend to bring new supplies of material carrying alumina into this outer zone, where it would be deposited as corundum. This is essentially Becker's theory of fractional crystallization; and it is noted that the high fluidity of these very basic magmas is a very favorable condition. W. O. C.

Erionite, a new Zeolite. By ARTHUR S. EAKLE. (*Am. J. Sci., 156, 66-68.*)

This mineral occurs as very fine, white, pearly and woolly threads, associated with opal in a rhyolyte-tuff from Durkee, Oregon. Analysis gives: SiO_2, 57.16; Al_2O_3, 16.08; CaO, 3.50; MgO, 0.66; K_2O, 3.51; Na_2O, 2.47; H_2O, 17.30; total, 100.68. Allowing one molecule of water as hydroxyl, as the hydration experiments indicate we obtain the formula $H_2\,Si_6\,Al_2\,Ca\,K_2\,Na_2\,O_{17} + 5H_2O$. This is analogous to the formula for stilbite with the calcium largely replaced by alkalies; but in other respects the new zeolite has no resemblance to stilbite. The name refers to its woolly appearance. An analysis of the associated milky opal gave: SiO_2, 95.56; H_2O, 4.14; and a trace of alumina. W. O. C.

Metamorphism of Rocks and Rock Flowage. By C. R. VAN HISE. (*Am. J. Sci., 156, 75-91; Bull. Geol. Soc. Am., 9, 269-328.*)

This important contribution to dynamical geology, which is condensed from a partly written treatise on metamorphism and the metamorphic rocks, is mainly a physical study; but the important coöperation of chemical agencies is fully recognized in the paragraphs on chemical action and its relations to heat and pressure, the upper and lower physico-chemical zones, etc. Vant Hoff's law that "on the whole, the preponderating chemical reactions at lower temperatures are the combinings (associations) which take place with the development of heat; while the reactions preponderating at higher temperatures are the cleavings (dissociations), which take place with the ab-

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sorption of heat," is made a basis principle of the discussion; and the contrasts of the upper and lower zones of the earth's crust resulting from this law and the natural antagonism of heat and pressure are traced out in hydration, the mutual replacements of oxygen and sulphur, carbon dioxide and silicon dioxide, and the tendency to develop in the upper zone minerals of lower specific gravity with consequent expansion of the rocks, and in the deeper-seated zone minerals of higher specific gravity, with consequent contraction of the rocks. In both the physical and chemical categories, alike at lesser and greater depths, water is recognized as the one important and essential medium of alteration; and an almost inappreciable proportion of water is regarded as sufficient for extensive and rapid metamorphism, in which it may act solely as agent, suffering neither gain nor loss. In this connection the author cites the experiments of Barus, according to which 180°C. is a critical temperature for the solution of glass in water, the action being very slow below this temperature and astonishingly rapid above it. The solution of the glass and crystallization of its derived minerals are essentially contemporaneous and continuous processes, involving, in the absence of hydrous derivatives, no necessary diminution of the water, which may continue its work as a mineralizer indefinitely and so rapidly as to dissolve and deposit in crystalline form a volume of glass equal to that of the water in about half an hour, from which the author calculates that, even if the rate for rocks be only one-thousandth that for glass, a rock formation could be dissolved and crystallized 50,000 times by one per cent. of water in a mountain-making period of 150,000 years. W. O. C.

Mineralogical Notes. By C. H. WARREN. (*Am. J. Sci., 156, 116-124.*)

This paper describes: 1. Melanotekite, a basic silicate or iron sesquioxide and lead, from Hillsboro, New Mexico, the analyses of exceptionally pure material indicating for this species and Kentrolite, the corresponding basic silicate of manganese sesquioxide and lead, the formula $Fe_4(Mn_4)Pb_2Si_3O_{18}$, instead of $Fe_2(Mn_2)Pb_2Si_2O_9$ heretofore accepted. 2. Pseudomorphs after phenacite, from Greenwood, Maine, in which gigantic crystals up to twelve inches in diameter having the form of phenacite have been completely replaced by a mixture of quartz and cookeite, with not a trace of beryllium remaining. 3. Similar pseudomorphs after large crystals of topaz from the same locality. 4. Crystallized tapiolite (tantalate of iron and manganese) from Topsham, Maine, which is distinguished by its tetragonal form from its orthorhomic dimorph, tantalite, and by its composition from the corresponding dimorphous niobates, mossite and columbite. 5. Crystallized tantalite from Paris, Maine, which is shown by its very high specific gravity (7.26) not to be columbite, while the absence of manganese adds to its chemical interest. 6. Cobaltiferous smithsonite from Boleo, Lower California, which had been mistaken for the rare hydrated cobalt carbonate, remingtonite, but which is found by analysis to contain 39.02 per cent. of ZnO and only 10.25 per cent. of CoO. W. O. C.

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Sölosbergyte and Tinguayte from Essex County, Mass. By HENRY S. WASHINGTON. (*Am. J. Sci., 156, 176-187.*)

The sölosbergyte forms a dike four feet wide cutting granite, and is specially distinguished by the presence of glaucophane and riebeckite. One complete analysis is given and compared with four analyses from other regions; and from the analysis the mineral composition is computed, the chief constituents, in order of abundance, being,—albite, orthoclase, glaucophane, riebeckite, quartz and titanite. In this connection an analysis is also given of the Quincy granite in which T. G. White had reported a blue hornblende which he referred to glaucophane; analyses of four foreign granites are quoted for comparison; and the calculation of the mineral composition gives, in order of abundance, quartz, albite, orthoclase, riebeckite and glaucophane, the riebeckite largely predominating over the glaucophane. The analyses are of special interest as pointing to the existence of a purely iron-alumina glaucophane.

The tinguayte also occurs as a dike in the granite; and its most notable characteristic is the occurrence in it, apparently as an original constituent, of a large proportion (37.4 per cent.) of analcite. As before, the analysis is compared with the similar rocks of other regions and the mineral composition is deduced therefrom. W. O. C.

Distribution and Quantitative Occurrence of Vanadium and Molybdenum in Rocks of the United States. By W. F. HILLEBRAND. (*Am. J. Sci., 156, 209-216.*)

The analytic data show the quantitative occurrence and distribution of vanadium in a large number (57) and variety of igneous rocks, in a few of the component minerals of these rocks, and in a few metamorphic and secondary rocks. Two of the samples in the last series were highly composite, one representing 253 sandstones and the other 498 limestones. The conclusions shown by a comparison of these data are: that vanadium occurs in quite appreciable amounts in the more basic igneous and metamorphic rocks, up to .08 per cent. or more, of V_2O_5, but seems to be absent or nearly so from the highly siliceous ones; that the chief source of the vanadium is the heavy ferric-aluminous silicates—the biotites, pyroxenes, amphiboles; that limestone and sandstones contain only very small amounts of vanadium; that molybdenum is confined to the more siliceous rocks; and so far has been found only in traces in these. W. O. C.

An Occurrence of Dunyte in Western Massachusetts. By G. C. MARTIN. (*Am. J. Sci., 156, 244-248.*)

The dunyte or olivine rock, of which only two other occurrences are known in North America, forms an irregularly elliptical boss of distinctly igneous origin, about 1,000 by 2,000 feet in extent, in the town of Cheshire. The olivine is extensively serpentinized, and the original accessories include chromite, magnetite and picotite. The olivine, purified by the Thoulet solution, gave on analysis: MgO, 51.41; SiO_2, 40.07; FeO, 4.84; Al_2O_3, 1.94; H_2O, 1.03; total, 99.29.

W. O. C.

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Chemical and Mineral Relationships in Igneous Rocks. By JOSEPH P. IDDINGS. (*J. Geol., 6, 219-237.*)

This is an attempt to correlate the mineral composition of igneous rocks with the chemical composition of their magmas; that is, of each rock as a whole. The chief difficulties are: first, the variable composition of the rock making minerals, quartz alone having an absolutely fixed composition, and no element occurring only in one mineral; second, the fact that no fixed association of minerals necessarily results from the crystallization of a magma, the result being largely controlled by the physical conditions. To avoid undue complexity, the author confines his attention to the more important rock-making minerals, including quartz, feldspathic minerals, micas, pyroxenes, amphiboles, olivine and magnetite. The empirical and dualistic formulas are given for each species; and the latter are classified in accordance with the ratios of the protoxide and sesquioxide bases to the silica. After quoting briefly some of the laws governing the relations of the mineral and chemical composition formulated in an earlier paper, the author discusses in greater detail and with the aid of diagrams, the relations particularly of quartz, and of leucite, nephelite and sodalite, thus making more evident the interdependence of the various minerals on one another and on the chemical composition of the magma. W. O. C.

A Study of some Examples of Rock Variation. By J. MORGAN CLEMENTS. (*J. Geol., 6, 372-392.*)

The rocks in question include diorytes, gabbros, norytes and peridotytes occurring in the Crystal Falls iron-bearing district of Michigan. Petrographic descriptions and chemical analyses of the several types are followed by discussion of their chemical relations, the complete analyses, percentages of the chief oxides, and atomic proportions of the metals being presented in tabular form, and the author concludes that the rapid changes in mineralogical composition and texture in a single rock exposure, and the changes thus occasioned from one rock into another through intermediate facies show very clearly the intimate relationship of the rocks to one another, and warrants the assumption that they all belong to a geological unit.

W. O. C.

Notes on some Igneous, Metamorphic and Sedimentary Rocks of the Coast Ranges of California. By H. W. TURNER. (*J. Geol., 6, 483-499.*)

The rocks considered in this paper include: 1. Metabasalts and diabases, formerly regarded as metamorphic sandstones, of which ten analyses are quoted without discussion. 2. Serpentine, which has also been regarded as, in part at least, altered sedimentary rocks, but which the author holds to be, in the main, at least, of igneous origin. Nine analyses, representing five localities are quoted, showing great uniformity of composition and indicating that olivine or rhombic pyroxene must have been a prominent constituent of all of the original rocks from which the serpentines were derived. 3. The Franciscan or

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Golden Gate formation. 4. The San Pablo formation, which contains layers of rhyolytic tuff or pumice, of which two partial analyses are given. W. O. C.

Syenite-porphyry Dikes in the Northern Adirondacks. By H. P. CUSHING. (*Bull. Geol. Soc. Am.*, 9, 239-256.)

These dikes, of which fourteen have been discovered, and which are shown by their field relations to be younger than the pre-Cambrian gneisses and anorthosytes which constitute the mass of the Adirondacks, and older than the Potsdam sandstone, consist of a sub-acid, holocrystalline rock chiefly composed of acid feldspars (microperthite, albite, orthoclase and microcline) and biotite, with less abundant quartz and hornblende, and accessory magnetite, hematite, apatite and titanite, and various secondary species. Three original analyses are given, selected to represent the mean and extremes of composition; and from these the percentages of the component minerals are deduced. In the discussion of the petrologic relationships of the dikes, numerous other analyses of the related rocks are quoted. W. O. C.

Clay Deposits and Clay Industry in North Carolina. By HEINRICH RIES. (*North Carolina Geol. Surv., Bull. 13, 1-157.*)

Although regarded as a merely preliminary report, this is a fairly comprehensive, if not a detailed, account of the clays of a great state. But it is not of local interest only, for the admirable introductory sections, forming nearly half the work, and covering the chemical and physical properties, mining and preparation, of the clays is general, and more specifically of the kaolins or china clays, pottery clays, fire clays and brick clays, must prove of general interest and value. Under the chemical properties of clays are discussed: the fluxing impurities, including the alkalies, compounds of iron, lime and magnesia; non-fluxing impurities, including silica titanium, organic matter and water; analytic methods; and the rational analysis of clays. The descriptive sections include nearly seventy original analysis of North Carolina clays by Prof. Chas. Baskerville of the State University; and these are reported in tabular form at the end of the report. Each analysis gives the silica, alumina, ferric oxide, lime, magnesia, alkalies, moisture and water; and in certain cases the ferrous oxide, organic matter, sulphur and titanic oxide were also determined. By way of rational analyses, on which the value of a clay chiefly depends, the clay substance (pure kaolin), free and total fluxes are given in each case; and for the china clays also the percentages of quartz and feldspar in the sand. W. O. C.

Weathering of Alnoyte in Manheim, New York. By C. H. SMYTH, JR. (*Bull. Geol. Soc. Am.*, 9, 257-268.)

The alnoyte, which forms several small dikes in the Calciferous "sand rock" on East Canada creek, is an ultrabasic type, consisting largely of biotite and serpentine derived from the original olivine, the olivine itself being extremely rare; and the minor constituents are mag-

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netite, apatite and perofskite, with secondary calcite. The investigation is largely based upon the methods established by Merrill. Both the fresh rock and its highly weathered faces were analyzed, the chief points of interest being, as usual, the increase of ferric oxide and water and diminution of ferrous oxide, alkaline earths and silica in the weathered material. From the analyses the loss for the whole rock, and the percentages of each constituent retained and lost are calculated. The titanic oxide is shown to be one of the most resistant constituents of the rock, its behavior being almost identical with that of alumina, so that the two are taken together as the basis for comparison. The iron oxides have proved almost equally insoluble, the apparent net increase being due, of course, to per oxidation of FeO. The large proportion of magnesia and lime in the weathered rock indicate that the process is far from complete; and in harmony with this view 93.60 per cent. of the weather rock was found to be soluble in hydrochloric acid and sodium hydrate solution. The contrast between the surface weathering and deep-seated alteration of rocks, the rate of decomposition of biotite, and the time of wathering are also discussed. Biotite appears to weather rapidly in acid rocks and slowly in basic rocks simply because, while it is chemically one of the weakest constituents of the former, it is one of the most resistant constituents of the latter, the difference being relative only. W. O. C.

Om ACEROCAREZONEN *ett bidrag till Kännedomen om Skånes Olenidenskiffrar*, af JOH. CHR. MOBERG och HJELMAR MÖLLER [Geol. fören i Stockholm förhandl., Bd. 20, Hf. 5, 1898.]

This valuable contribution of Moberg and Möller to a knowledge of the upper Olenus schist of Scania largely extends our knowledge of the range of the genus Acerocare. Hitherto we have thought it was confined to the layer immediately beneath the Dictyonema shale, but this essay shows that it had a wider range, viz: through the whole thickness of the Peltura or upper Olenus schist, and that the type of the genus *A. ecorne* Angelin, in place of coming at the top of this fauna, is really at the base. The genus is carried up through the Peltura beds by several species, one described by Linnarsson, and several new, by these authors. They also describe a new species of Parabolina, and give fuller illustrations of *P. heres* Brögger, than had been given by the author of the species. The figures of this species differ considerably from Brögger's, notably in the heavy wrinkling of the test, and the deep glabellar furrows. One valuable feature of this work is that young head shields are figured, thus giving a much better conception of the genetic relationship of the species, than the figures of adult shields alone would give.

The authors relegate *Olenus acanthurus* Ang. which Brögger had placed in Protopeltura (Brög) to Parabolina, Salter. Acerocare is regarded as a genus closely related to Peltura, differing from it in the spineless pygidium etc.

An excellent feature of this article is that restorations of the complete form of most of the species described are given, and the hypostome also in most cases. Five excellent plates accompany the article, and leave

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one little to wish for as regards a complete knowledge of these interesting species of the upper Olenus beds.

The species described are *Acerocare ecorne* Ang., *A.* (*Cyclognathus*, Lin'rs.) *micropygum* Lin'rs, *A. norvegicum*, n. sp. *A. granulatum*, n. sp. *A. paradoxum*, n. sp., *A. tulbergi*, n. sp., *A. claudicans*, n. sp., *Parabolina acanthura* Ang., *P. heres* Brögg., *P. megalops*, n. sp., *Orthis*, sp.

G. F. M.

UEBER CALYMMENE, *Brongniart*, von J. F. POMPECKJ, in München. [Neues Jahrbuch für Mineralogie, Geologie und Palæontologie, Stuttgart, 1898.]

Dr. Pompeckj has made an exhaustive study of the genus Calymmene, Brongn. He cites F. Schmidt as having divided the genus into three sections. 1. *Calymmene, sens strict.*, with the type *C. tuberculata Dalm* (= blumenbachi). 2. *Pharostoma* Corda, Type, *C. pulchra* Barr., and 3. *Ptychometopus*, F. Schmidt. The author supports Brögger in considering *Calymenopsis*, Bergeron, as superfluous, *C. fillacovi* being a variety of *Euloma ornatum* Ang.

Dr. Pompeckj proposes an arrangement of the forms referred to Calymmene somewhat different from F. Schmidt's. He would divide the genus into two main sections; the first (A) containing the groups (1) *Pharostoma* Corda, and (2) *Calymmene*, s. strict., F. Schmidt. Both of these Pompeckj would include under CALYMMENE proper. The second section (B) to contain the groups of (3) *C. tristani* Brong. (4) of *C. arago* Row., and (5) of *Ptychometopus*, F. Schmidt. This section Pompeckj calls SYNHOMALONOTUS.

Frech considers Euloma, Angelin, as the stem genus of Pharostoma, but Pompeckj regards Bavarilla of Barrande as holding this place. He looks to Neseuretus, Hicks, as the source of the B section, and he regards Homalonotus also as having sprung from this source (page 248). Should not Section B then be referred to Homalonotus rather than Calymmene?

G. F. M.

The Special Report on Kansas Coal. ERASMUS HAWORTH; W. R. CRANE. (Univ. Geol. Sur. Kansas, vol. III, 347 pp., Topeka, 1898.)

The third volume of geological notes, that has been recently issued under the auspices of the University of Kansas, presents much interesting information regarding the sunflower state. It purports to be a special report on the coals. As a whole it gives us our first connected review of the Kansas Carboniferous below the so-called Permian.

When it is remembered that this work is done largely without financial compensation, too much credit cannot be bestowed upon the Kansas geologists who have thus so generously given their services to their State. It behooves the great State of Kansas, so rich in mineral wealth, to be equal to the occasion and aid this most worthy undertaking in a manner more befitting her already exalted position. Professor Haworth, speaking not of his own labors but of those who have rendered him assistance says that the greater part

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of this work "was done wholly without expense to the State, and that the remainder was done at such a nominal expense that it is almost without a parallel in the history of public investigations of this kind." The same remark is equally true of all of this Kansas work. It is the plain duty of the State to encourage these efforts so well begun. From a financial standpoint, let alone all others, it would be a good investment to Kansas to extend liberal aid. For every dollar thus expended the return is a thousand to the citizens at large. Such commendable activity as is shown by the Kansas workers should not be allowed to go without public recognition in the way of ample funds to still further enable this most laudable enterprise to go on as it should.

The first part of the volume, by professor Haworth, gives a complete summary of all the work previously done by the instructors and students of the university during the prosecution of the university geological survey, so far as this has pertained to the coal measures. The various terranes before recognized are described anew, some new divisional lines are made and some new names of formations are proposed. The classification now presented is essentially as follows:

Divisions of the Kansas Coal Measures.

Upper Coal Measures	Cottonwood Formation	Cottonwood shales. Cottonwood limestone.
	Wabaunsee Formation	Limestones and shales, to which names have not been given as yet. Burlingame limestone.
	Shawnee Formation	Osage shales. Topeka limestones. Calhoun shales. Deer Creek limestone. Tecumseh shales. Lecompton limestones. Lecompton shales.
	Douglas Formation	Oread limestone. Lawrence shales.
	Pottawatomic Formation	Garnett limestones. Lane shales. Iola limestones. Thayer shales. Erie limestones.
Lower Coal Measures	Marmaton Formation	Upper Pleasanton shales. Altamont limestone. Lower Pleasanton shales. Pawnee limestone. Labette shales. Oswego limestones.
	Cher'kee sh'l's	Cherokee shales.

The second part, by Mr. W. E. Crane, which makes up the greater portion of the volume, is devoted chiefly to the commercial aspects of the Kansas coal, the methods of mining and the character of the mine machinery. A considerable portion of this embraces also many details regarding the stratigraphy and the local peculiarities of sec-

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tions. The chemical and physical properties of the coals are considered at length. The statistics of output and values are graphically shown. The report closes with a mining directory and a chapter on mining laws.

Much as we are indebted to professor Haworth and his assistants for the great mass of facts presented, there are certain features for which geologists are not so thankful. Some of these features were prominently displayed in the earlier volumes of the series. They were passed over at the time for the reason that it was thought that succeeding accounts would have these evils corrected. Instead they have been greatly intensified. It therefore seems well to call attention briefly to a few of them. While it is acknowledged that much of the work in Kansas was done under great difficulties, and that the principal author was plunged suddenly from his chosen field of mineralogy to the wholly different one of stratigraphy, these conditions hardly justify the position taken by him. Outsiders seek, and seek in vain, for any progressive purpose in the proposing of so many undefined and hence meaningless and useless titles for insignificant beds, and various terranes. The author himself appears to have questioned the good form of such action. The excuse that they are "only local" seems worse than no excuse at all. To be sure the beds are local. But as soon as they are printed the names are the common property of the entire geological world; and necessarily form a part of geological literature, even if most of them must be relegated to the vast realm of the spurious.

Since the appearance of the first volume of the series, of which the work under consideration is a part, geologists especially interested in the American Carboniferous have been not a little curious to know just what principles professor Haworth worked upon in his Kansas investigations. Volume III gives for the first time an insight into those principles. The startling statements are made that "Nomenclature, coupled with the claims of priority, is the bane of the scientist;" and that "It frequently happens that an investigator in a new field knowingly substitutes new names for old, sometimes with good reason, and sometimes apparently largely to have his name connected with future discussions of allied subjects." These two sentences form the key-note to the whole theme, and enable us to understand more easily why professor Haworth has been unable to solve satisfactorily the problems presented.

The principles involved in the consideration of some of the points hereafter mentioned are of far wider than local significance. Did they but affect Kansas alone the subject might be dismissed without further reference. The first of the sentences just quoted is indeed remarkable, and particularly as coming from the source that it does. Its author can hardly have intended its literal meaning, yet perusal of the rest of the paragraph precludes any other interpretation. Most people regard nomenclature as a means whereby thoughts are exactly expressed. Terms are employed in the same way that the carpenter

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uses his tools. Should we paraphrase the sentence just alluded to, and say that "his tools are the bane of the carpenter," we would be generally regarded as talking at random. We have identically the same conditions. There are but few of us that could be induced to believe that progress is possible along any such lines. It is not the use of rational nomenclature but the constant abuse of it that causes widespread irritation among scientists.

The second sentence quoted appears to apply too truly to Kansas to have it emanate from professor Haworth. It has been with keen regret that geologists have witnessed how professor Haworth has so persistently and perfectly ignored his predecessors in the Kansas field. In all the three volumes he has published not a single definite statement is gleaned that any one else had ever seen the coal measures of that region. No one could ever gather from these notes that such able geologists and indefatigable workers as Swallow, Hawn, Meek, Broadhead, Hayden, St. John, Hay, Mudge or Newberry had ever crossed the Kansas boundaries. Yet their labors are vastly more important than those carried on during the past lustrum. Even the footnotes, with few exceptions, are manifestly merely references to show Haworth's "claims of priority." One cannot help concluding from these writings that there was certainly "an investigator in a new field."

In this connection we cannot gloze it over "on account of an inexcusable ignorance of the subject at hand on part of the writer." We cannot but feel that a gross injustice has been done not only to the earlier writers, by ignoring completely their work, much of it far superior to that done to-day, but also to the geologists now actively interested in the region, who have no means of connecting the results of the pioneers with those lately added. These pioneers are worthy of better treatment. If ever there was a proper place to bring together all the results accomplished in Kansas it was in connection with the work under consideration. The contrast is enormously accentuated by the careful efforts of Prosser, who has published some of his results in the same volumes, and who has so correlated the earlier work as to increase its value ten-fold, at the same time vastly illuminating his own.

Little need be said of professor Haworth's arrangement of the terranes that he recognizes. A classification based solely upon "convenience" cannot endure. The many incongruities arising from grouping upon this principle are only too apparent. These may be considered in another connection, and so passed over here.

The remarks on priority show a marvelous inappreciation of the common canons of nomenclature. Yet this is not wholly unexpected when we consider in what a baneful light all terminology is held by the Kansan author. If some of the ordinary rules of the use of terms had even a slight consideration many of the formidable difficulties raised by professor Haworth would have been easily dispelled before they appeared. The general statements regarding the use of

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Primary, Secondary, Permian and similar geological terms are as much out of place that they indicate a lack of recognition of the broad fact that terminology must change with conceptions that have been outgrown.

By wholly ignoring the excellent and extensive labors of his predecessors professor Haworth has fallen into grievous errors regarding many of his new names. It will necessitate herculean "struggles to avoid obscurity" of some of them. Marmaton is essentially the same subdivision which Bain, several years ago, gave the name Appanoose. Erie has been already preoccupied a dozen times. Thayer was a term given by Broadhead, 30 years ago, to the same shales at the same locality in Neosho county. Broadhead's full and lucid description of identically the same section could be with great advantage today substituted for the one given by Haworth. Lawrence, Iola and Cherokee are about the only important titles out of all the numerous ones proposed that are likely to stand. Surely, even a little attention to previous work would have removed most if not all of the conditions "compelling the new invesigator to discontinue some of the terms and making it desirable if not necessary for him to introduce others." With no consistent principles to be guided by, perhaps little else could be expected. There is, at least, no internal evidence that professor Haworth has given the slightest attention to that generally recognized principle that terminology reflects systematic arrangement. The latter is manifestly an expression of genetic relationship. Classification based entirely on convenience is no classification at all. It is merely titled chaos. C. R. K.

Contribution à l'étude micrographique des terrains sédimentaires, par LUCIEN CAYEUX. (Mémoires de la Société Géologique du Nord. tome 4, pp. 589. 10 pls. quarto, 1897. Lille.)

This is in part a contribution to metamorphism, and it is certainly one of the most important that have been made to that subject. It has long been known that amongst the older rocks, and especially the Archean, the constituent fragmental grains undergo transformations which result in new minerals and in compact crystalline rocks. In this work the process is studied at its commencement, and in the Cretaceous and Tertiary strata. The research is carried on with thoroughness and deliberation. In the examination the author has included also the microscopic organisms of all the formations described. These formations are the Jurassic and Cretaceous of the Paris basin, the Cretaceous of Belgium, the Eocene shales and glauconitic sands of the north of France and the chalk of the Paris basin.

All literature on these formations, at least so far as it bears on the microscopic structure and organisms, appears to have contributed to the wealth of reference and to the grasp of the subject shown by the author; and at the close of the volume is an extended bibliography embracing 312 works, beginning in 1745 with Linneus and ending with Gosselet in 1897.

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It is useless to attempt to fully analyze this work. A simple mention of the secondary minerals discovered in these sedimentary strata will convey but an imperfect idea of the transformations that are described. Glauconite figures very largely, also quartz and the compounds of lime; among the species mentioned being orthoclase, gypsum, calcite, leverrierite, opal, pyrite, limonite, chalcedony, chert. Amongst the clastic minerals are mentioned zircon, tourmaline, (these two also sometimes apparently formed *in situ*) rutile, magnetite, orthoclase, plagioclase, anatase, brookite, chlorite, staurotide, garnet, apatite, corundum, ilmenite, disthene, and several others undetermined. A plate is devoted to the microscopic crystals. Their forms are so perfect that nearly all of them appear not to have suffered any transportation, a fact which suggests that many if not all of them are indigenous.

The author has given much time to the study of the various forms of glauconite and to the question of its origin. He brings to light some new facts and verifies others not well known. Amongst the characters of this mineral he emphasizes the following: With generally rounded forms and olive green color, its grains are also sometimes black; in thin section they vary from yellowish green to dark green with specific gravity from 2.2 to 2.83. Most glauconite is homogenous in structure, but it is sometimes granular, globular and concretionary. It also acts as a pigment in a manner similar to limonite, when it is impossible to separate it from the siliceous or argillaceous substratum which it colors. It is cleavable, as shown by the author in 1893, a fact which has since been recognized by Lacroix who has determined the basal cleavage (001) similar to that of the micas and chlorites. This cleavage is difficult, fine or coarse, inequally spaced, rare or frequent. The partings are rarely straight, being more often slightly sinuous or wavy. They are parallel or convergent; they even cut each other, when they are very irregular. These features are illustrated by figures.

Glauconite sometimes includes mineral and organic substances, the former being usually quartz (which very rarely is traversed by rutile) feldspar and calcite, the latter microscopic forms and fragments of foraminifera and radiolarians. Sollas has also noted coccoliths and coccospheres while Murray and Renard found in the glanconite collected by the Challenger, particles of quartz, magnetite and other minerals.

The cleavable grains of glauconite are sensibly polychroic. This was announced by Cayeux in 1892, and, as with black mica, the greatest absorption takes place when the cleavage is parallel to the principal section of the analyser. The mineral is then dark green, and when perpendicular to the cleavage its color changes to light yellow.

By the aid of studies of Calderon and Chaves, and especially of

*Mineralogie de la France et de ses colonies, I 407.

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Lacroix, M. Cayeux is now able to add to the simple announcement of double refraction of glauconite made by him in 1892, the essential characters of a crystalline substance, viz: it is biaxial (sometimes apparently uniaxial) the angle of the optic axes being from 30 to 40 degrees. The value of $n_g - n_p$ is about 0.020, and from analogy with the micas and chlorites it is supposed to be monoclinic. Glauconite has also been found, though very rarely, to have a radiated-fibrous or concretionary structure giving a black cross in thin section.

In the discussion of the phenomena of alteration of glauconite, the author bears directly on the theory of Spurr of the origin of the great deposits of iron ore of the Taconic in Minnesota. He says: "The products of decomposition of glauconite are hydrates of the oxide of iron and pyrite." Most frequently alteration begins to appear at the periphery and extends progressively and regularly to the interior. It also reaches the center of the grains by way of fissures which traverse them in all directions. The products of decomposition appear not only throughout the areas that are altered but they migrate sometimes and color the surrounding parts and encrust surrounding minerals. Alteration may make its first appearance at the center of the grains as in the Meule de Thivencelles, for example, where it affects a great number of grains; grains are there found transformed into hydrated iron oxide excepting only a slight superficial zone which remains intact."

Matthew has also found a notable amount of oxide of iron in the Cambrian of New Brunswick wherever foraminiferal remains, and hence glauconite, occur, the two being reasonably taken to be complementary.

According to Dr. Cayeux: (1) Glauconite has been formed in other places than those in which its grains now exist, and has shared in the processes of mechanical transport in the same manner as grains of sand. (2) It contains inclusions of other minerals, such as magnetite and quartz. (3) Forms incrustations on crystals of orthoclase, microcline, etc., penetrating along the cleavages even to the center of the grains. (4) Serves as a pigment in the same manner as limonite. (5) Takes the form *globulaire*, like nascent quartz crystals described by Fouqué, and by combination of these globules grows into larger and larger groups and masses. (6) Its grains take complete outward form but do not sometimes fill up the interior, only a skeleton of glauconite occupying the space. (7) Continues to increase after the deposit of the rock which contains it. (8) Forms at different dates, cotemporary with the consolidation of the rock and posterior to it. (8) Sometimes replaces calcite, taking the form of calcite rhombohedrons. (9) Is usually, but not always, dependent on organic substances for its genesis. N. H. W.

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MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Bagg, R. M., Jr.

The Cretaceous foraminifera of New Jersey. (Bull. 88, U. S. Geol. Sur., pp. 89, 6 pls. 1898.)

Bailey, "Prof."

The bay of Fundy trough in American Geological History. (Trans. Roy. Soc. Can., 2nd ser., vol. 3, sec. 4, pp. 107-116, 1897.)

Boyer, Charles L. (Lewis Woolman and).

Fossil mollusks and diatoms from the Dismal swamp, Virginia and North Carolina; indication of the geological age of the deposit. (Proc. Acad. Nat. Sci. Phil., Part 2, April-Sept. 1898, pp. 414—)

Brush, Geo. J.

Manual of Determinative Mineralogy, with an introduction on Blowpipe Analysis. Revised and enlarged, with new tables for the identification of minerals, by Samuel L. Penfield, 15th Edition, 1898, pp. 312. John Wiley and Sons, New York.

Claypole, E. W.

Glacial Theories—cosmical and terrestrial. (Am. Geol., vol. 22, pp. 310-315, Nov. 1898.)

Dawson, Sir J. W.

On the genus Lepidophloios as illustrated by specimens from the coal formation of Nova Scotia and New Brunswick. (Trans. Roy. Soc. Can., 2nd Ser., vol. 3, Sec. 4, pp. 57-77, 14 pls., 1897.)

Dawson, Geo. M.

Annual Report. [Geological Survey of Canada.] New Series, vol. 9, 1896, (1898), pp. 816, maps; contains the director's summary report for 1896, and reports of Tyrrell, Bell, Low, Bailey, Hoffman and Ingall, and 20 plates.

Eastman, C. R.

Some new points in dinichthyid osteology. (Am. Nat., vol. 32, pp. 747-768, Oct. 1898.)

Ells, R. W.

Notes on the Archean of Eastern Canada. (Trans. Roy. Soc. Can., 2nd Ser., vol. 3, Sec. 4, pp. 117-124, 1897.)

Fitzpatrick, T. J.

The drift section and the glacial striæ in the vicinity of Lamoni, Iowa. (Iowa Acad. Sciences, vol. 5, pp. 105-106, 1 pl., 1898.)

Gannett, Henry.

Lake Chelan. (Nat. Geol. Mag., vol. 9, Oct. 1898, pp. 417-428.)

*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

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Girty, Geo. H.

Description of a fauna found in the Devonian Black shale of eastern Kentucky. (Am. Jour. Sci., Nov. 1898, pp. 384-394, 1 pl.)

Herrick, C. L.

The occurrence of copper and lead in the San Andreas and Caballo Mountains. (Am. Geol., vol. 22, pp. 285-291, Nov. 1898.)

Hidden, W. E.

Occurrence of sperrylite in North Carolina. (Am. Jour. Sci., Nov. 1898, pp. 381-383.)

Hill, R. T. (and T. Wayland Vaughan).

The Lower Creteceous Gryphæas of the Texas region. (Bull. No. 151, U. S. Geol. Sur., pp. 66, 35 pls., 1898.)

Hopkins, Thos. C.

Concentric Weathering in sedimentary rocks. (Bull. Geol. Soc. Am., vol. 9, 1897, pp. 427-428, 3 pls.)

Ingall, E. D.

Section of Mineral Statistics and mines; annual report for 1896. (Geol. Sur. Can. Ann. Report, New Series, vol. 9, 1898, pp. 172.)

Keyes, C. R.

Some geological formations of the cap-au-gres uplift. (Proc. Iowa Acad. Sciences, vol. 5, pp. 58-63, 3 pls., 1898.)

Keyes, C. R.

Carboniferous formations of the Ozark region. (Iowa Acad. Sciences, vol. 5, pp. 55-58, 1898.)

Keyes, C. R.

Geographic development of the Crimea. (Iowa Acad. Sciences, vol. 5, pp. 52-54, 1898.)

King, Francis P. (W. S. Yates, S. W. McCallie and).

A preliminary report on a part of the gold deposits of Georgia. (Bull. 4-A, Geol. Sur. Georgia, pp. 542, maps, 21 pls., 1896.)

Ladd, Geo. E.

Geological Phenomena resulting from the surface tension of water. (Am. Geol., vol. 22, pp. 267-285, pl., Nov. 1898.)

Lucas, F. A.

Contributions to paleontology. (Am. Jour. Sci, Nov. 1898, pp. 399-400.)

Manson, Marsden.

The laws of climatic evolution. (Brit. Assc. Adv. Sci., Bristol meeting, 1898.)

Marsh, O. C.

The value of type specimens and importance of their preservation. (Am. Jour. Sci., Nov. 1898, pp. 401-405.)

Marsh, O. C.

The origin of Mammals. (Am. Jour. Sci., Nov. 1898. pp. 406-409.)

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McCallie, S. W.

The occurrence and history of gold. (Bull. No. 4-A, Geol. Sur., Georgia, 1896, pp. 7-32.)

McCallie, S. W. (W. S. Yates and Francis P. King).

A preliminary report on a part of the gold deposits of Georgia. (Bull. 4-A, Geol. Sur. Georgia, pp. 542, maps, 21 pls., 1896.)

McGee, W. J.

The Geospheres. (Nat. Geog. Mag., vol. 9, Oct. 1898, pp. 435-447.)

Rawson, F. Leslie.

Some lava flows of the western slope of the Sierra Nevada, California. (Bull. No. 89, U. S. Geol. Sur., pp. 74, 11 pls., 1898.)

Sardeson, F. W.

Intraformational conglomerates in the Galena series. (Am. Geol., vol. 22, pp. 315-323, pl., Nov. 1898.)

Sardeson, F. W.

Remarks on the loess. (Proc. Iowa Acad. Sciences, vol. 5, p. 11, 1898, [abstract].)

Todd, J. E.

Degradation of loess. (Proc. Acad. Sciences, vol. 5, pp. 46-51, 1898.)

Tyrrell, J. B.

Report on the Doobaunt, Kazan and Ferguson rivers, and the northwest coast of Hudson bay, and on two overland routes from Hudson bay to lake Winnipeg. (Geol. Sur. Can., Rep. 9, New Series, May 10, 1897, 11 plates.)

Upham, Warren.

Giants' kettles near Christiania and in Lucerne. (Am. Geol., vol. 22, pp. 291-299, Nov. 1898.)

Vaughan, T. Wayland (Robt. T. Hill and).

The Lower Cretaceous Gryphæas of the Texas region. (Bull. 151, U. S. Geol. Sur., pp. 66, 35 pls., 1898.)

Walcott, C. D.

Fossil Medusæ. (Mon. XXX, U. S. Geol. Sur., pp. viii and 201, pls. 47, 1898.)

Walker, T. L.

Causes of variation in the composition of igneous rocks. (Am. Jour. Sci., Nov. 1898, pp. 410-415.)

Weeks, F. B.

Bibliography and index of North American geology, paleontology, petrology and mineralogy for the year 1896. (Bull. No. 149, U. S. Geol. Sur., pp. 152, 1897.)

Weeks, F. B.

Bibliography and index of North American geology, petrology and mineralogy for the year 1897. (Bull. 156, U. S. Geol. Sur., pp. 130, 1898.)

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Winchell, N. H.

Origin of the Archean igneous rocks. (Am. Geol., vol. 22, pp. 299-310, Nov. 1898.)

Woolman, Lewis (and Charles S. Boyer).

Fossil mollusks and diatoms from the Dismal swamp, Virginia and North Carolina; indication of the geological age of the deposit. (Proc. Acad. Nat. Sci., Phil., Part 2, April-Sept. 1898, pp. 414—)

Wright, G. Frederick.

Glacial Observations in the Champlain-St. Lawrence valley. (Am. Geol., vol. 22, pp. 333-334, Nov. 1898.)

Yeates, W. S. (S. W. McCallie and Francis P. King).

A preliminary report on a part of the gold deposits of Georgia. (Bull. 4-A, Geol. Sur. Georgia, pp. 542, maps, 21 plates, 1896.)

PERSONAL AND SCIENTIFIC NEWS.

MR. OSCAR H. HERSHEY, of Freeport, Illinois, returned home November 14th, from the Isthmus of Panama, where, in this and a former journey, he has united geological observation with gold prospecting.

MR. J. B. TYRRELL, for 15 years past one of the geologists of the Canadian survey, spent the past summer in the Yukon district. He is now planning to engage in economic explorations and surveys in the vicinity of Dawson, leaving Ottawa about the first of January. He will be prepared to report on the extent, character and value of mining properties.

DR. M. E. WADSWORTH has resigned the presidency of the Michigan College of Mines, to take effect May 15, 1899. Dr Wadsworth was also granted leave of absence from Dec. 23, prox. In his letter of resignation he calls attention to the growth of the institution since his administration began, and to the excellent condition in which he leaves it. "The stormy and arduous duties" of president of such an institution have not such attraction as the quiet and peace of a professorship, and Dr. Wadsworth desires to complete sundry scientific work which was begun long ago—an accomplishment which he has found impossible with the executive duties of the presidency resting on him.

MR. GEORGE BIRD GRINNELL, in *Science* of November 18, describes a visit made by him to the Blackfoot mountains in northwestern Montana, accompanied by Mr. J. B. Monroe. Two important geographic points were established, viz: the location and character of the Pumpelly glacier, and the po-

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sition of Avalanche basin. This glacier rises to the hight of several hundred feet above the face of a lofty cliff, over which portions of the glacier are constantly falling, with tremendous reports which are heard for a long distance. This glacier is a part of the southward flow of the ice cap which covers almost the whole of the Blackfoot mountain, The Blackfoot glacier flows northeastwardly from the peak of Blackfoot mountain, six or seven miles long and three or four miles wide. Another glacier flows northerly between Mt. Kainah and Mt. Jackson, while from Mt. Jackson, the highest of all these mountains, a number of smaller glaciers flow down to the timber line. Another glacier of considerable dimensions lies in Pinchot's basin, southward from Mt. Jackson.

DR. OTTO NORDENSKJÖLD, UPSALA, returning from Alaska where he has spent the summer, passed two days at Minneapolis recently. Dr. Nordenskjöld has now seen the extremes of the western hemisphere, having spent last year in southern Patagonia and Terra del Fuego. His reports on these expeditions are awaited with much interest.

MR. J. E. SPURR, in the service of the U. S. Geol. Survey, has also recently returned from Alaska, stopping at Minneapolis en route to Washington. He left Seattle with a party of seven April 4, and was picked up by the steamer *Dora* Oct. 31 at Katmai, which was the last trip of the last steamer from the northern portion of Alaska for the season of 1898. By way of Cook's inlet, Mr. Spurr reached the Sushitna, and then the Kuskokwim, descending the latter. Then he ascended the Kanektok to Togiak lake from which he descended the Togiak river. Then partly by a coastal route and partly by small rivers he reached Nushagak, from which he went across Bristol bay, via Naknek river and lake and over the Alaskan peninsula to Katmai where he was making preparations for a possible winter sojourn when he was unexpectedly rescued by the Dora on her last trip.

THE METRIC SYSTEM. The following bill, approved by the Committee on Coinage, Weights and Measures, is pending in Congress:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after the first day of July, nineteen hundred, all the departments of the Government of the United States, in the transaction of all business requiring the use of weights and measurement, except in completing the survey of the public lands, shall employ and use only the weights and measures of the metric system, and from said first day of July, nineteen hundred, the metric system of weights and measures shall be the legal standard of weights and measures recognized in the United States.

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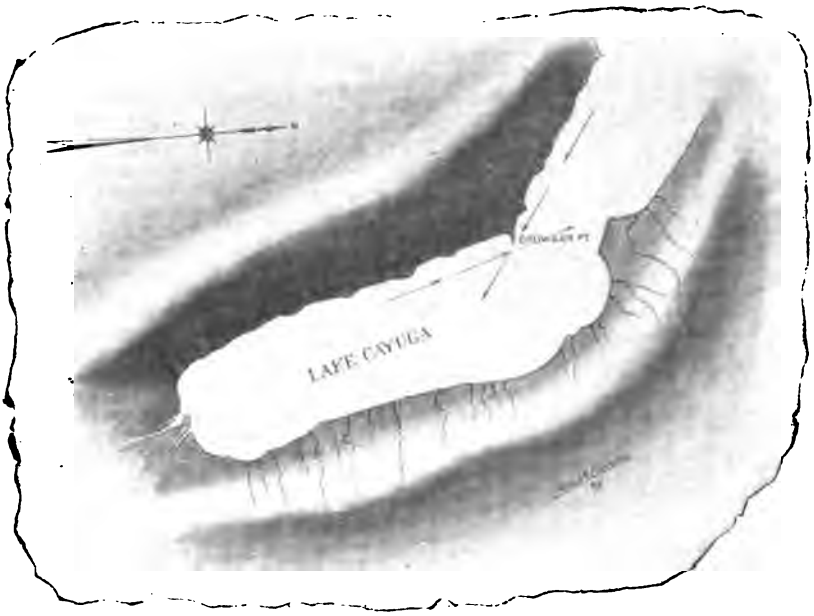


FIG. 1. To illustrate position of Crowbar point.



FIG. 2. North arm of cuspate foreland at Sydney, Cape Breton island. View taken from near base.

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FIG. 1. View of base of cuspate foreland, Sydney, Cape Breton island. View taken from same point as figure 2, of plate I. Source of the materials shown in the sea cliff.



FIG. 2. Barrachois hook, Bras d'Or, Cape Breton island. Right hand, north; left hand, south or side open to strong waves.

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FIG. 1. Island tied to mainland by two bars, Bras d' Or, Cape Breton island. Cause somewhat resembling that of the cusps.



FIG. 2. Very perfect cuspate foreland, Bras d'Or, Cape Breton island, projecting from a point.



FIG. 3. Bar connecting islands and bar from islands growing toward a bar developing from the mainland on the least protected side.

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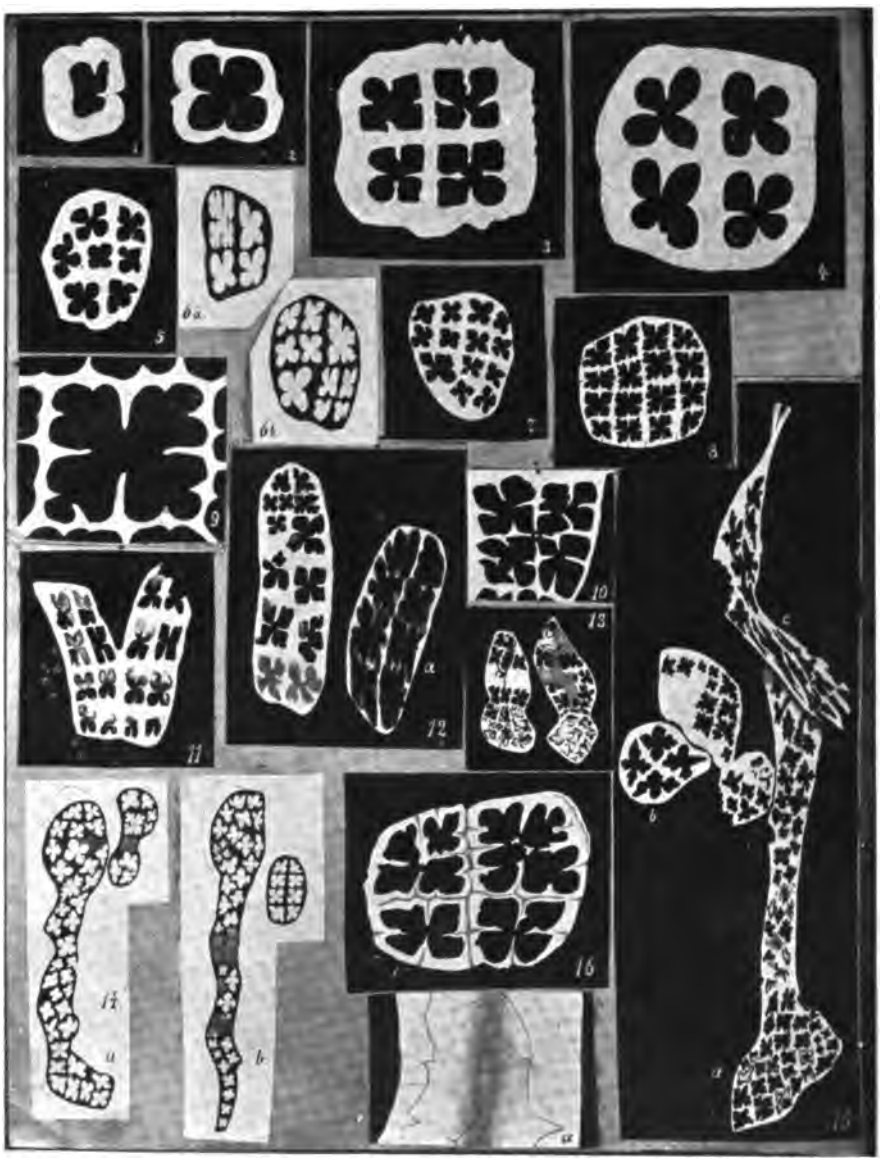
FIG. 1. Extreme tip of Barrachois hook, Bras d'Or, Cape Breton island, showing coarseness of material composing it.



FIG. 2. A spit, hooked at the end and growing toward the shore to form the other arm of a cusp.

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Tetradium Cellulosum Hall, SP.

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FIG. 1. Neck of the Bernalillo volcano.



FIG. 2. Adjacent part of the stratified material showing dykes from the neck and the disturbed strata.

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VIEW ON THE CHATTAHOOCHE RIVER.

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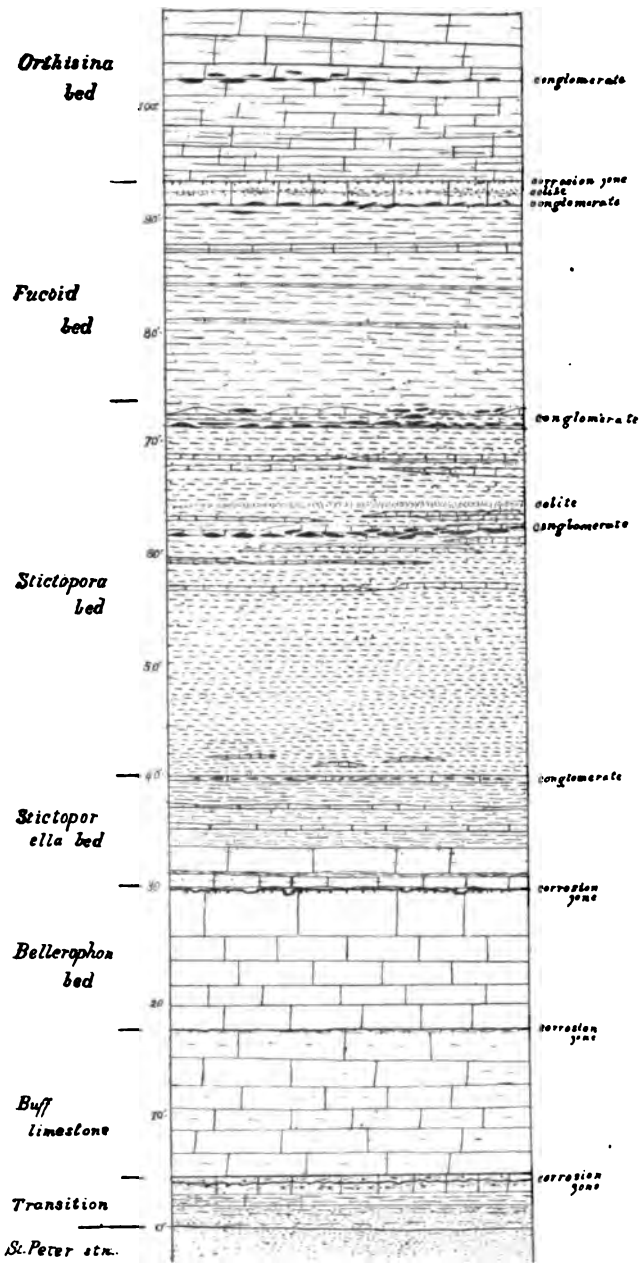
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VIEW ON THE CHATTAHOOCHE RIVER.

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Section of the Galena series showing corrosion zones and conglomerates.

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